

Pointing, swaying, and walking towards tomorrow: The
link between spatial metaphor and body movements in
Mandarin and English

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To My Parents, my wife Ni Zhou and our cat.

Abstract

English and Mandarin use different linguistic metaphors to encode time. English uses the sagittal dimension (with the future as front as in *looking forward*), whereas Mandarin tends to use both the vertical (with future as down: ‘*lower week*’ means next week and the sagittal dimension (with future as back: ‘*back day*’ means the day after tomorrow). Existing studies have shown that English speakers conceptualize time both sagittally and transversally, whereas Mandarin speakers conceive time both sagittally and vertically. It has been suggested that the different temporal directions on the sagittal dimension between the two languages are likely to be caused by the different emphases of temporal models: Moving Ego model vs. Moving Time model. The future is associated with *front* in the Moving Ego model; whereas the future is associated with *back* in the Moving Time model. While a large amount of literature has focused on differences across the two languages in terms of using different dimensions, very little has looked at differences that exist within dimensions.

This paper examines the explicit and implicit associations between time and direction held by speakers of these languages. I tested how language and overtly embedded spatial information (spatio-temporal metaphor) can affect people's perception of time across three groups of speakers: English and Mandarin monolinguals, and Mandarin-English bilinguals. By using quantitative data that were collected from three experiments: 1. testing how people point directions, 2. testing body sway directions and 3. testing walking speeds, we found that:

Experiment 1 (a pointing task) showed that English monolinguals associated the future with front and up; the overt encoding of metaphor has a significant effect in Mandarin (the future as front and up unless the overt cue ‘back’ and ‘lower’ appears) but not in English; and bilinguals showed intermediate tendencies, which were significantly different from English and Mandarin monolinguals, suggesting that the knowledge of one language could

affect how the bilinguals process temporal information in the other language. The association between up and the future from all the groups is new and unexpected, which needs to be further tested in future studies.

Experiment 2 (a body-sway experiment) showed that the differences between swaying forward and swaying backward were mostly consistent with temporal directions in both English and Mandarin during thinking (replicating results for English from Miles, Nind, & Macrae, 2010), talking and listening. English speakers swayed more forward for the future than for the past when thinking and talking about personal lives, which was consistent with the Moving Ego model. However, they swayed more backward for the future (later) than for the past (earlier) when listening to stories, which was inconsistent with the Moving Ego model. Bilinguals in the Mandarin condition swayed more forward for the past than for the future when thinking and talking about personal lives and listening to stories, which was consistent with the dominant temporal direction in Mandarin (the Moving Time model). However, when in the English condition, they swayed more forward for the future than for the past during listening, which was consistent with the Moving Ego model, and they swayed more backward for the future than for the past during listening and talking, suggesting a persistence of impact from their native language. Moreover, overt spatial information in Mandarin such as *front* and *back* in temporal phrases had immediate effects on bilinguals' body sway directions during perception: they swayed more forward when they heard *front*, and more back when they heard *back*. Part of the results (e.g., English monolinguals) from the story listening part are inconsistent with existing studies and theories. Given that the stories were not designed as minimal pairs, these results from the listening part should be treated as preliminary results and should be interpreted with caution.

Experiment 3 (a walking experiment) showed that temporal information only affected English monolinguals' walking speeds, and their walking speeds when listening to stories were inconsistent with the Moving Ego model. However, bilinguals walked faster when listening to English stimuli than when listening to Mandarin stimuli. Given the fact that the English stimuli had more stressed words than the Mandarin stimuli, it was speculated that the rhythm of auditory stimuli might have resulted in the different speeds between En-

glish and Mandarin. Nevertheless, these results were also collected from the stories that were used in the body sway experiment, and they also should be treated as preliminary results and should be interpreted with caution.

The current study tested cross-linguistic influences on the perception of temporal information from an embodied point of view. It found that both spatial information that is embedded in temporal information and the language that is used to express the information could affect how people conceive time. The processing of temporal information in different languages, including thinking and talking about one's life in the past and in the future, were found to be accompanied by body sway to different directions consistent with the direction of time in the corresponding language. These results replicated existing work (e.g., Miles, Nind, & Macrae, 2010) and further explored body sway patterns during metaphorical thinking.

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Chapter I

Introduction

This thesis is about temporal metaphor and the perception of temporal information. More specifically, I investigated how monolingual English and Mandarin speakers, as well as Mandarin-English bilinguals may perceive related temporal expressions differently and whether the different temporal directions in the two languages can be revealed by different body movement patterns from their speakers; and if there are any effects of overt spatial information embedded in temporal information (spatio-temporal metaphoric language) on participants' bodily behaviours. Therefore, the main aims of the current study are to compare the effect of the processing of temporal information on body movements from two languages if time is described as in different directions between the two languages, and to study the effect of overt spatial cues on people's body movements. The reason for choosing the two languages is as follows: both languages use spatial words to describe time; the two languages use similar (horizontal) and different (horizontal versus vertical) physical dimensions, and in the shared (horizontal) dimension, time might have different directions in the two languages.

The findings in this thesis are related to how people use bodily experience in order to understand concepts. I have combined studies and findings on conceptual metaphor, the relationship between bodily experience and concepts, perceiving temporal information in different languages on different axes and gesturing. By testing bilingual speakers of Mandarin and English on how they think about time in an explicit task and implicitly respond to auditory temporal information, and how they implicitly respond during perceiving and producing temporal information, I have related the results to conceptual metaphor and embodied cognition. However, I argue that the views suggesting that temporal reasoning interacts with bodily experience

can account for the current findings. Therefore, I propose that the differences between English and Mandarin on how their speakers conceive time, which are both cross-dimensional and within-dimensional, can be revealed by gesturing and implicit association between time and body sway.

I designed three experiments and tested them on different language speaking groups. Each of the experiments is capable of answering research questions that will be addressed throughout the course of the literature review in the second chapter. For each experiment, we obtained quantitative data and conducted statistical analyses by using mixed effect logistic and linear regression models. However, due to some methodological problems in part of the second experiment and the third experiment, some results from these two sections should be treated as preliminary results, and they needed to be further tested in future studies.

In chapter 2, I will discuss the ideas of conceptual metaphor and particularly in the current context, spatio-temporal metaphor and the perception of temporal information, and their relationships to gesture. I will also talk about findings of the perception of time that are based on the view of embodied cognition, as well as discussing the implications and the major focus of the current study. The current study focuses on body movements on speakers of two languages that have opposite temporal directions. Both hand movements and body movements will be studied, however, body movements are not traditionally treated as gesturing owing to their subtle moving size and lack of visible identification. Body movements can be seen as another window on people's cognitive process. This chapter also develops the research questions.

In Chapter 3, I will talk about the design and the result from quantitative statistical analysis from the first experiment, which was a pointing experiment and served as a pilot study. Its first purpose was to look at how English and Mandarin speakers and bilinguals of the two languages associate time with direction differently on each dimension. Secondly, by gathering data from different language speakers, it was hoped to establish patterns for different language speaking groups and therefore establish different patterns that could be used as reference points in the design of the following experiments.

Chapter 4 will focus on the second experiment: testing how people sway their bodies while doing three different tasks. The experiment consisted of three parts: thinking, talking, and listening. The thinking part was for replicating results from an existing study (Miles, Nind, & Macrae, 2010) and the talking part extended this to see if the results generalize to contexts in which individuals are speaking out loud. There were two experiments which involved listening and I will address them as perception experiments. One was to test a combined effect of language and overt cues and the other was to test a separate effect of the two. The experiment was inspired by an existing study in which people's body-sway was tested when they were asked to think about their lives in the past and in the future (Miles, Nind, & Macrae, 2010). If actively thinking about one's future and past can make people lean forward and backward respectively, people might also have similar behaviour when they passively listen to information about the future and the past as well as engaging in talking about their lives in the future and in the past. More importantly, bilingual speakers whose two languages have different temporal directions might have different behaviours depending on which language context they are in.

In Chapter 5 I will present and discuss the third experiment. The third experiment tests whether the effect of temporal direction is general enough to affect people's walking speeds. I predicted that the direction of time might have a sagittal meaning and therefore can affect people's walking speeds. If people's body sway directions are congruent with the temporal direction in each language, then people's walking speeds might be reduced if one's direction of walking is contrary to the direction embedded in the temporal information, or the speeds might increase if one's direction of walking is the same as the direction embedded in the temporal information.

In Chapter 6 I will first summarize the overall results and at the same time answer the research questions that will be asked throughout the course of Chapter 2. I will also discuss the current findings, their implications and their connections to conceptual metaphor theory, and the contributions of the current study.

Before presenting the methodology and results for each experiment, in the next chapter I will provide the literature review for the current study,

and at the same time raise questions that have not been answered in the literature and state several research questions that will be addressed in the current study.

Chapter II

Background

This study focuses on how English and Mandarin speakers associate time with space differently, and on testing the effect of language contexts on how Mandarin-English (ME) bilinguals produce body movements during the processing of temporal information. The starting point of this study is based on an existing study of native English speakers' body sway patterns (Miles, Nind, & Macrae, 2010), in which it was found that native English speakers sway bodies forward when thinking about their future and backward when thinking about their past. It remains unclear whether these particular movement patterns are caused by temporal direction in English (front-future and back-past), or caused by the fact that forward is the natural movement direction for humans. It is also unclear whether the participants in their study really thought about the temporal events that were required by the experiment. Therefore, the current study aims at testing whether speakers of a language that associates forward with the past (Mandarin) would still show these movement patterns. It mainly asks four general questions regarding the two languages that have different emphases on temporal sequences that lead to opposite temporal directions on the sagittal axis (front-back). The general questions are concerned with:

1. Whether English speakers associate front with the future and whether Mandarin speakers associate back with the future.
2. If English and Mandarin speakers show different preferences toward time-direction associations, whether they would show opposite body sway patterns during the processing of temporal information: forward for the future in English and forward for the past in Mandarin.
3. If the processing of temporal information has different effects accord-

ingly on body sway patterns between speakers of the two languages, whether such effects can be found from larger body movements.

4. Whether overtly embedded spatial information in temporal information would have effects on their direction-time associations.

More specific questions for the four questions will be mentioned in the current chapter. Since the association between time and space is based on Conceptual Metaphor Theory (CMT), I will first talk about conceptual metaphor. After that I will focus on one type of conceptual metaphor, namely spatio-temporal metaphor, and factors that affect how humans conceive of time in different physical dimensions. After that, I will summarize past research and findings on spatio-temporal metaphors and the relationship between time and direction in English and Mandarin. This summary will lead to my first research question. Following that, I will discuss the usefulness of analyzing gestures in studying spatio-temporal metaphors and the mental representation of time, and the connection between the perception of abstract concepts and motor control. Such discussion is necessary because not only does it build the foundation for the methodology of the current study, but also leads to my second research question. After that, I will talk about the connection between perceived body movement, spatio-temporal metaphors and the mental representation of time, which will lead to my third research question. Last but not least, I will talk about the effect of overt spatial information (spatio-temporal metaphoric language) in the perception of time in Mandarin, and this will lead to my last research question.

2.1 Metaphors and Conceptual Metaphor Theory

Before discussing any approaches that studied metaphor, it is important to consider what metaphor is. Metaphor is comparative, which means a metaphor always compares two things. For example, the sentence *he is boiling mad* compares a person with hot fluid. Despite the fact that metaphor can have many definitions, the core idea is that metaphor involves talking about things in terms of other things. Metaphor is traditionally defined as an unusual form of discourse and it is “a poetically or rhetorically ambitious use

of words, a figurative as opposed to literal use” (Hills, 2011). The description draws a distinction between literal language and figurative language, and highlights that metaphor was studied as a distinct linguistic phenomenon.

In the nineteen eighties, a new way of theorizing about language and thought, especially about metaphor, was initiated by George Lakoff, Mark Johnson, Ronald Langacker and their followers, and this new trend later became known as Cognitive Linguistics (Hills, 2011). Cognitive linguists argue against the framework of Chomsky's generative grammar which treats language as symbols combined with universal grammatical rules. Generative grammar is a theory that argues that a language is governed by a system of rules, and this rule system is mostly unrelated to meaning. Generative grammar also argues that there is a universal grammar that is innate to human brains. On the contrary, in cognitive linguistics, linguistic structures are believed to reflect certain cognitive properties because linguistic expressions are related to people's different views about different concepts, which are related to meaning (Lee, 2001).

Lakoff and Johnson's work (1980/2003) treated metaphor not as an unusual way of expression, but as a fundamental property of the everyday use of language, which means that metaphors exist in our normal daily conversation and most of our fundamental concepts. For example, we look at social status as if it is related to height as in *social ladder*, we pass our thoughts to others as if they are in a package such as *give a good idea*, and we see personal life as a journey as in *It's been a long road*. Lakoff and Johnson's book “Metaphors we live by” (1980/2003) established a foundation for CMT. The theory states that every abstract concept (such as social ladder, information and life) has its metaphorical basis, and each metaphor is a mapping between a concept and a concrete experience. Based on the theory, a metaphor is a mapping between an abstract concept and a concrete domain. For example, the expression *he is boiling mad* is based on the metaphor ANGER IS HOT FLUID. More examples were also given by the theory (Lakoff & Johnson, 1980/2003), for example, ARGUMENT IS WAR, TIME IS MONEY, HAPPY IS UP, SPACE IS CONTAINER, and TIME IS MOVEMENT, etc. Within each metaphor, there are many metaphoric expressions. Table 2.1 gives examples for each type of metaphor listed above. The theory explains

several fundamental metaphors that are used by people in daily life, such as orientational metaphors, ontological metaphors and structural metaphors. More specific explanations for these types of conceptual metaphors will be given later in this chapter.

Table 2.1: Examples of metaphoric expressions in different metaphors (Lakoff and Johnson, 1980)

Metaphor	Metaphoric Language
ARGUMENT IS WAR	Your claims are indefensible.
TIME IS MONEY	You are wasting my time.
HAPPY IS UP	You are in high spirits.
SPACE IS CONTAINER	He is out of sight now.
TIME IS MOVEMENT	I look forward to the arrival of Christmas.

Conceptual metaphor is also directly related to embodied cognition or grounded cognition. In fact, conceptual metaphor is often seen as a case of grounded cognition (Barsalou, 2008). Grounded cognition claims that the meaning of concepts, our perception and our mental representation of the world are grounded in everyday embodied experience (Lakoff & Johnson, 1999). Based on grounded cognition, CMT agrees that mental concepts are derived from concrete bodily experience. As we can see, CMT emphasizes the importance of the interaction between the human body and the environment. Embodied cognition will be discussed in more detail later in this chapter.

In works by cognitive linguists (Casasanto, 2010; Clark, 1973; Lakoff & Johnson, 1980/2003), it is argued that when people use metaphorical language, not only do people talk about one thing in terms of another, but they also think about it in such a way. For example, Gibbs (2013) conducted two sets of experiments that tested people's interpretation of two love stories. He found that people who heard the story that described love as a successful JOURNEY walked longer in time and distance than people who heard the story that described love as an unsuccessful JOURNEY. More importantly, no differences were found for the stories that did not use the metaphor, suggesting that thinking about a particular conceptual metaphor could affect certain patterns of body movement, and understanding a metaphor is based

on embodied simulation of the metaphorical action and real action. According to CMT, abstract concepts are often expressed as physical entities such as people's body parts, physical feelings, concrete matters and prepositions (Casasanto, 2009; Gibbs, Lima, & Francozo, 2004; Kövecses, 2003; Lakoff & Johnson, 1980/2003; Yu, 1995, 2003, 2008). For example, in Mandarin, courage is described as gallbladder (Yu, 2003). In English, prepositional words are frequently used to express abstract meanings. For example, *up* means happy and active as in HAPPY IS UP, and *down* means sad and depressed as in SADNESS IS DOWN. *In* is used when describing a situation as if it is a container. For example, in the prepositional phrases *in trouble* and *in sight*, the former describes a situation as if someone is in it, whereas the latter treats the entire visual range as if it is a confined space. The words *before* and *after* are used in both spatial and temporal sequences.

Each conceptual metaphor contains two domains: the source domain and the target domain. The target domain is the idea we are trying to express and understand, and the source domain is the concrete domain we can directly feel and perceive. A frequently cited example from CMT is ARGUMENT IS WAR, in which WAR is the source domain and ARGUMENT is the target domain. Argument is like war because one can attack and defend and one can win and lose. Another example is LOVE IS A JOURNEY, in which LOVE is the target domain, and JOURNEY is the source domain. Mappings between the two domains are mostly unidirectional. In other words, the relationships between the source domain and the target domain are mostly asymmetrical (Gibbs, 1996; Glucksberg & Keysar, 1990). For instance, people talk about love in terms of a journey, but people never talk about a journey in terms of love. The reason for this directionality is that the source domain is more concrete and the target domain is more incomplete and vague (Gibbs, 1996).

Although conceptual metaphor has been extensively studied in the last few decades, CMT was criticized for circular argumentation, and various studies provided alternative ways of accounting for metaphors such as the categorization view (Glucksberg & Keysar, 1993), the conceptual blending theory (Fauconnier & Turner, 1996) and the Similarity View (Murphy, 1996). The current study does not involve comparing CMT to other approaches, since cross-domain mapping and the embodiment approach can well explain

the use of spatial information during temporal processing. However, it is necessary to point out that, although CMT can provide a theoretical framework for the current study and explain its findings, I do not intend to exclude the possibility of other explanations, such as the Similarity View formulated by Murphy (1996), which argues that the reason people use concrete domains to describe abstract domains is because the source and the target share similar structures. This view has also been applied to the similarity between time and space (Galton, 2011). It is also important to point out that the explanation for one type of metaphor may not necessarily work for other types:

We need to be careful in not assuming that theories proposed to explain one kind of figurative language use (e.g., metaphor) necessarily apply to explaining other instances of figurative language interpretation (e.g., irony or metonymy) (Gibbs, 2001, p.325).

2.2 *Spatio-Temporal Metaphors and Embodied Experience and Time*

There are three main types of conceptual metaphor: structural, orientational and ontological (Lakoff & Johnson, 1980/2003). The three types of conceptual metaphors are not mutually exclusive, which means that a metaphor can fit into more than one category. Structural metaphors are metaphors that apply an entire structure from the source domain to the target domain. For example, ARGUMENT IS WAR. In this metaphor, the structure of ARGUMENT is a projection from the structure of WAR, so during argument one can *attack*, *defend*, and use *strategies*, which are the expressions originally used in WAR. Ontological metaphors refer to the use of an abstract concept as if it is an object and therefore has physical boundaries. For instance, the visual field is seen as a container in metaphors such as *in sight*; and information is seen as a package in the conduit metaphor. The last type of conceptual metaphor that is mentioned by CMT is orientational metaphors. In orientational metaphors, abstract concepts are associated with directions. For example, valence and social status are associated with height as in the metaphor MORE IS UP and SOCIAL LADDER. Another example of an

orientational metaphor, which is the major focus of the current study, is the spatio-temporal metaphor: TIME IS SPACE. Spatio-temporal metaphors are orientational metaphors (Lakoff & Johnson, 1980/2003), which means that the concept of time is based on the physical environment; and in this case, space. Strictly speaking, spatio-temporal metaphors can be both structural and orientational because the whole structure of time is systematically mapped onto space, and each language develops a system of using spatio-temporal metaphors, which will be discussed later in this chapter.

As we can see, in CMT, abstract ideas are described and understood through concrete domains. The next section is about embodied cognition, which suggests that people's cognitive processes are grounded in other domains.

2.2.1 Embodied Cognition

Before discussing the perception of time as embodied cognition, I first need to talk about embodied cognition, since I have mentioned it several times and it is directly related to conceptual metaphor. More importantly, it is related to the current study. CMT states that people conceptualize the world based on concrete domains. As mentioned, CMT is often taken as an example of embodied/grounded cognition. Grounded cognition states that cognition are tied to perceptual experience (Barsalou, 1999), and activating a mental concept involves perceptual and motor simulations of the properties related to the concept (Hostetter & Alibali, 2008). It means our cognitive processes are deeply grounded in our physical experience, such as the contextual situation, interaction with the physical environment and action (Wilson, 2002), whereas others argued that cognition is grounded in simulation, situated action and bodily states (Barsalou, 2008). According to embodied cognition, the cognitive mental representation of meaning is derived from sensorimotor experience. For example, episodic memory can consist of visual information: when we recall an event we recall what we saw, including specific visual details. Sensory and motor information are also stored in our conceptual system: such as how we interact with the world and in what kind of situation; all this information is stored in our conceptual system. Therefore,

when we recall information, related information will also be recalled and simulated such as the visual information, the context and the action. Embodied cognition builds a bridge between the physical environment, and the mental representation and conceptual structure, and the link is our interaction with the world. We use our body to interact with the environment and by doing so we can receive sensory input. At the same time, we store the information encountered into our conceptual structure and react to it as an output: the sensory and motor systems are like input and output devices (Wilson, 2002). Our thoughts would be empty if there were no sensing or acting because there would be no input and output (Robbins & Aydede, 2009).

As an example of embodied cognition, cognitive linguists argued that abstract thinking is based on concrete physical experiences (Lakoff & Johnson, 1980/2003), and that means that bodily actions could affect cognition. Many studies that have been conducted have supported the idea of embodied cognition. Gibbs (2006) found that bodily actions could affect how well people can understand metaphorical actions. Boroditsky and Ramscar (2002) found that people who experience different motion would provide different answers to an ambiguous question related to temporal ordering. They found that people who experienced body movements are more likely to think a meeting would be on Friday if the meeting on Wednesday was moved forward two days. Furthermore, by studying co-speech gestures, which is a type of gesture that is exclusively produced during spontaneous speech, Chui (2011) found that metaphorical thought is expressed by gestures and both gesture and language share metaphorical mappings. As we can see, studies on embodied cognition often looked at the effect of bodily experience and the human body, and the processing of temporal information can be affected by body movement. However, the question is, whether the effect of the processing of temporal information would affect body movements. For example, can certain body movements be affected by the processing of temporal information? This is what needs to be answered in the current study.

2.2.2 Spatio-Temporal Metaphors and Embodied Cognition

According to CMT, time is understood through space. In fact, the use of spatial information in temporal expressions in language attracted people's attention even before CMT was developed. For example, Traugott (1978) described the use of spatial words in temporal expressions; and Clark (1973) argued for the two types of temporal models in English: Moving Ego and Moving Time models/metaphors. In both models, temporal events are seen as their relationships to the observer, that is, the ego. In the Moving Ego model, temporal events are seen as a sequence of events located on an axis and the ego moves along the axis. Therefore, future events are ahead of the ego and past events are left behind the ego such as in 'Christmas is before us' and 'The history is behind us'. The word *before* is related to the future because it is further in the direction of motion. Whereas in the Moving Time model, the ego does not move; however, instead, a sequence of temporal events move through the ego. In the Moving Time model, *before* is related to an earlier event such as in 'The revolution was over before breakfast' (Boroditsky, 2000). There has been a renewed interest in how humans conceive of time since the turn of the century (Boroditsky, 2000), because new studies combined CMT with linguistic relativity and embodied cognition, and the new approach discovered interesting but controversial findings. For example, Boroditsky (2001) and Boroditsky, Fuhrman, and McCormick (2011) noticed that Mandarin uses vertical spatial words in temporal expressions and by using both explicit questions and behavioral experiments, she found that Mandarin speakers use the vertical dimension to think about time more often than do English speakers. Boroditsky claimed that such a finding on the perception of time can be seen as evidence for supporting linguistic relativity: speakers of the two languages conceive of time on different dimensions. However, some others failed to replicate Boroditsky's results and therefore criticized her for not using non-linguistic tasks (some of them used linguistic materials). They argued that using linguistic materials to test linguistic relativity would lead to circular argument and the findings could be language-specific effects. For example, Chen (2007) conducted a similar experiment but was not able to replicate Boroditsky's results. Moreover, Chen

and O'Seaghdha (2013) also criticized Boroditsky for confusing the distinction between non-language-specific and non-linguistic effects, and therefore raised the issue of using linguistic materials to gain evidence about linguistic relativity, especially about how people conceive of time across cultures. However, testing tasks that involve linguistic materials are sometimes inevitable when testing people's understanding of temporal expressions, which means linguistic materials are needed. This issue will be further discussed later when I discuss the difference between English and Mandarin on how they use spatial words to encode time.

Spatio-temporal metaphors draw a link between time and space, which means that people understand time in terms of space. CMT also states that orientational metaphors are based on bodily experience. Similarly, based on embodied cognition, time is also understood through embodied experience. Findings in the last decade on the connection between embodied cognition and spatio-temporal metaphors and temporal judgment were mostly derived from the theory of conceptual metaphor (Lakoff & Johnson, 1980/2003) as an embodied perspective, and were based on proposed extended new hypotheses. For example, studies have tested new hypotheses such as the effect of experienced movements on judging temporal sequences (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Matlock, Ramscar, & Boroditsky, 2005), the effect of writing direction on perceiving temporal order (Fuhrman & Boroditsky, 2010; Fuhrman et al., 2011), and the mutual effect between the perception of time and body movements (Hartmann & Mast, 2012; Miles, Betka, Pendry, & Macrae, 2010; Miles, Karpinska, Lumsden, & Macrae, 2010; Miles, Nind, & Macrae, 2010). As we can see, these models draw a link between temporal perception and bodily experience. These findings and models will be discussed later in this chapter.

2.3 The Relationship between Time and Space

Spatio-temporal metaphors are characteristic of conceptual metaphors in that they have an asymmetrical mapping between the source and the target. People use spatial language for temporal expressions but almost never use temporal language for spatial expressions. Casasanto and Boroditsky (2008)

found in six experiments that irrelevant spatial information affects adults' judgments of duration more than temporal information affects their spatial judgments. Later in a study, Casasanto, Fotakopoulou, and Boroditsky (2010) tested children and found that spatial information affects children's temporal judgments more than temporal information affects their spatial judgments. These studies suggest that the relationship between space and time in mental representation is asymmetrical. Eikmeier, Schröter, Maienborn, Alex-Ruf, and Ulrich (2013) also suggested that the representation of time is embedded in the representation of space, which means that space and time could be asymmetrically related, and their experimental results suggest that space and time are also strongly connected. On the contrary, Walsh (2003) argued that the processing of time and space share the same cortical metrics, suggesting that space and time are closely linked. Walsh based his argument on neurological data which showed shared brain areas were activated when processing space and time. However, as Casasanto et al. (2010) pointed out, Walsh's theory implicitly assumes that time and space are symmetrically related.

Apart from how space and time are related, it has been argued that the structure of space is imported into the structure of time (Boroditsky, 2000). Studies of children's language acquisition report that children acquire spatial words earlier than temporal words (Clark, 1973). Iossifova and Marmolejo-Ramos (2013) found that when being asked to point to directions for space and time, normally developing children between ages 4 and 5 are two times more likely to correctly point for space than for time¹; however, children between ages 6 and 7 are likely to correctly point for space and time equally, suggesting that spatial meanings are acquired earlier than temporal meanings. These findings also suggest that the structure of time might originate from the domain of space. Kemmerer (2005) argued that the spatial meanings are always chronologically primary, whereas the temporal meanings of spatial words are developed later based on tests on patients with brain damage. Such a theory is supported by the study of the change of semantic meanings

¹ Incorrect answers were: A. answering questions verbally when being asked to point directions. B. pointing to themselves when asked to point to space and time. C. pointing to more than one direction when being asked to point to time.

through history (Hopper & Traugott, 2003) as well as a survey of fifty-three different languages, which shows that most of temporal expressions originate from spatial expressions (Haspelmath, 1997).

As has been mentioned, the major focus of the current study is to explore the interaction between space, time and action. If space and time are strongly connected, then the processing of temporal information could affect people's body movement patterns. The connection between temporal reasoning and body movements has been tested in a few studies but not fully explored. Experimental psychologists and linguists have tried to find connections between people's mental representation of time and bodily experiences, and collected empirical data. Findings on these connections will be presented later in this chapter.

In the rest of the section, I will talk about some main characteristics that are shared by time and space, and people's mental representations of time that are formed on the basis of these characteristics. It is important to consider these characteristics since the current research and many existing studies are based on them. The main characteristics shared by time and space are extension, linearity, and directionality.

2.3.1 Extension, Linearity, Directionality and Transience of Space-Time

Galton (2011) listed four characteristics of time, which he called 'Attributes of Time'. The four attributes are extension, linearity, directedness and transience. He also considered whether the four attributes can apply to space and concluded that extension, linearity and directedness can be attributes of time as well as attributes of space, whereas transience can only be an attribute of space in special circumstances.

Extension refers to the fact that time can have different moments. Events can take a certain amount of time, whereas space can have area and volume. Linearity refers to the idea that time is linear, whereas space can also be linear. Directness means that time has directions, for example, people experience time from the past to the future as an "arrow of time" (Bender & Beller, 2014). Space itself does not have directions. However, human bodies are asymmetrical and objects can move through space. Lastly, transience is

the only attribute of time that is not fully shared by space. Time is transient, which means that each moment can only be experienced once, and it can be an attribute of space only under certain circumstances. For example, transience can be an attribute of space when space and time are correlated, such as experiencing the passing of both time and space when sitting in a moving vehicle.

As we can see, attributes of space seem to be less restricted than those of time. In the next section, I will talk about how humans and human languages associate time with space (direction) on different physical dimensions. These associations are based on the shared attributes of linearity and directionality between time and space. After that I will mainly discuss the two languages that are focused on in this study.

2.3.2 The Relationship between Linearity and Directionality of Time in Language and Perception

So far I have talked about the three attributes that are shared by time and space. In this section I will discuss the relationship between them in language and human perception of time. I am also going to talk about an important characteristic of the relationship between them, which is dimensionality.

The relationship between linearity and directionality is simple: time is linear and therefore time can have directions, and different directions can exist in any dimension in a three-dimensional world. Each language or culture adopts a unique way of conceptualizing time. Time is linear in many languages and cultures. For example, as Hall (1976, p.16) stated:

For M-time (monochronic time) people reared in the North European tradition, time is linear and segmented like a road or a ribbon extending forward into the future and backward to the past.

Linear time allows people to perceive time as an “arrow”; thus time can have directions. When the mental representation of time has a direction, a mental time line is formed through education in a specific culture or language in which the direction of the timeline needs to be meaningful. A mental time line that moves FORWARD to the future is meaningful in a culture when the

culture is future oriented. A mental time line in a culture that sees the past as AHEAD is based on the view that the past can be seen (Evans, 2003). A culture that has a writing system which writes vertically will perceive the future as downward (Fuhrman et al., 2011). A culture that sees THE FUTURE WILL BE BETTER and UP IS GOOD will perceive FUTURE IS UP (Lakoff & Johnson, 1980/2003). Therefore, since the relationship between time and space could be linear, a mental time line could be formed on three different axes. In the following sections, I will talk about factors that shape directionalities of the mental time line on the sagittal (front-back), vertical (up-down), and transverse (left-right) dimensions. These three dimensions are also important for the current study, which will test English and Mandarin speakers within each of the three dimensions.

2.3.2.1 The Relationship between Time and Space on the Sagittal Dimension

In many languages, time is described and perceived on the sagittal dimension. Let us use English as an example since English belongs to this group. In English, people use spatio-temporal metaphoric language on the sagittal dimension to describe temporal sequences. English has two types of temporal models (or temporal metaphors): the Moving Ego metaphor and the Moving Time metaphor (Clark, 1973; Lakoff & Johnson, 1980/2003). The differences between the Moving Ego and Moving Time metaphors have been observed by multiple authors (Evans, 2003; McTaggart, 1908; Moore, 2006; Traugott, 1978). In the Moving Ego model, time is seen as a sequence of temporal events and the ego moves towards later events and leaves earlier events behind. For example, English speakers can say ‘We are approaching Christmas.’ In this sentence, Christmas is seen as a time point in the future and the observer moves along the time-line and approaches the particular time point. The second type of temporal model is the Moving Time model, in which the ego does not move, but instead, a sequence of temporal events moves through the ego. For example, people can say ‘Christmas is approaching’.

English is one typical example that uses the Moving Ego metaphor with

the future ahead. English speakers tend to think that the future is in front of them and the past is behind them. Evidence for this has been found by using a range of experimental methods (Kranjec & McDonough, 2011; Miles, Nind, & Macrae, 2010; Sullivan & Barth, 2012). What is more, this way of perceiving the directionality of time is also shared by many languages and cultures, such as German speakers (Eikmeier et al., 2013; Koch, Glawe, & Holt, 2011; Ulrich et al., 2012).

Other languages which have not been influenced by western cultures adopt a completely different temporal direction. The Aymara language, which is spoken in Bolivia, Peru and Chile, associates front with the past and back with the future (Núñez & Sweetser, 2006); moreover, Aymara speakers' hand gestures are consistent with the direction of time in the language. The Aymara language is not the only language that uses an unusual temporal direction. Other languages that exhibit some temporal directions that are different from the Moving Ego metaphor in English such as Māori, a language spoken by Māori people in New Zealand (Thornton, 1987), also associate front with the past and back with the future.

Each language adopts its own way of understanding time. As has been mentioned, future oriented linear time tends to lead speakers to think of the future as ahead whereas people can see the past, which tends to lead speakers to think of the past as ahead. On the one hand, people walk forward and when we need to achieve goals we physically move forward to do things, thus, bodily experience leads us to associate forward with things that have not yet been done, that is, future goals (Natanzon & Ferguson, 2012). On the other hand, people know the past and have no idea what will happen in the future. The history can be seen so people associate the past with what is in front of them; the future is unknown so people may think of the future as behind them where they cannot see it (Núñez & Sweetser, 2006).

A culture can also have two different temporal directions on the sagittal dimension. For example, de la Fuente, Santiago, Román, Dumitrache, and Casasanto (2014) tested both younger and older Spaniards and found that the majority of the former group associated the future with front, whereas half of the latter group associated the past with front. The reason for such a difference is what is called the Temporal Focus Hypothesis (de la Fuente et

al., 2014), which states that whether people associate the future or the past with front depends on whether they focus more on future growth or cultural tradition. A similar but different phenomenon can be found in Mandarin, when the word *qian* (front) can sometimes mean the future, although in most cases it is related to the past (Yu, 2012). Spatio-temporal metaphors in Mandarin will be further discussed later in this chapter.

2.3.2.2 The Relationship between Time and Space on the Vertical Dimension

Apart from thinking about time on the sagittal (horizontal) dimension, people also use the vertical dimension to describe time. Mandarin Chinese is a typical example of a language where time is described on both the sagittal and the vertical dimensions (Scott, 1989), and Mandarin vertical temporal direction has been frequently documented. This does not mean Mandarin speakers use the vertical dimension more than the horizontal one. Studies show that in fact Mandarin speakers use the sagittal dimension more often than the vertical one. A corpus study (Chen, 2007) showed that the proportion of use of the vertical dimension to describe time is approximately 36% in written Mandarin. Another study (Boroditsky, 2008) indicated that Mandarin speakers used the vertical dimension to think about time 42% of the time in an experiment. Taken together, these studies suggest that the vertical dimension is used to perceive and describe time in Mandarin approximately 40% of the time. This means that Mandarin speakers use the vertical dimension to talk about time more often than speakers of other languages such as English. English also uses the vertical dimension in expressions such as “hand down knowledge from generation to generation” (Boroditsky, 2001); however, such a phenomenon is very rare in English. The use of the vertical dimension to describe time might have cultural reasons. For example, writing direction was from up to down before it was influenced by western cultures. Calendars in China were traditionally written vertically, and if a month passed, people had to move one page up in order to get to the next month. In addition, China has a tradition of burning incense sticks. When incense is being burned, it changes in length from long to short, and people

see it as marking the passing of time.

In order to investigate the effect of vertical writing/reading direction on temporal perception, Bergen and Lau (2012), used a non-linguistic task to make a comparison between English monolinguals, ME bilinguals from Mainland China and ME bilinguals from Taiwan on how they arranged cards that depicted temporally related events, and they found that English speakers only arranged cards from left to right and Mandarin speakers from Mainland China and Taiwan also arranged cards from top to bottom. When comparing Mandarin speakers from different regions, they found that people from Taiwan arranged cards from top to bottom more often than people from Mainland China.

Another study was conducted on people from Hong Kong and Macau (de Sousa, 2012), and the finding was that the participants from Hong Kong and Macau did not arrange time from top to bottom as often as people from Taiwan. This was probably because vertical writing in the two regions has become less common over the past few decades than in Taiwan. Evidence from the studies mentioned above suggests that the effect of vertical writing direction on temporal perception exists, and the likelihood of arranging time from top to bottom is dependent on language and the amount of exposure to vertical writing/reading.

One other thing that needs to be mentioned is that time might still have a direction on the vertical dimension in languages that do not use the vertical dimension often. For instance, as mentioned, English also uses the vertical dimension (in some time expressions); and the vertical direction of time in English is from bottom to top (Radden, 2004). This vertical direction of time in English probably has to do with the known past and the unknown future. In English, KNOWN IS DOWN and UNKNOWN IS UP as in “That's up in the air” and “The matter is settled” (Lakoff & Johnson, 1980/2003). The other explanation is that the association between time and vertical direction is indirectly connected by the association between valence and vertical direction, and that between time and valence. In the orientational metaphor, GOOD IS UP and THE FUTURE WILL BE BETTER (Lakoff & Johnson, 1980/2003), therefore, THE FUTURE IS UP.

However, existing studies did not find any preferred vertical directions in

English speakers (e.g., Boroditsky, 2001; Boroditsky et al., 2011; Miles, Tan, Noble, Lumsden, & Macrae, 2011). It has been argued that English might not have a vertical timeline for at least two reasons. First, temporal expressions that use *down* (e.g., *passing down to generations*) are not paired with those that use *up*; and second, if temporal meanings are expressed through spaital meanings, then *up* might not have a temporal meaning since *up* sometimes does not even have a spatial meaning (e.g., *turn up*, Casasanto & Jasmin, 2012).

2.3.2.3 *The Relationship between Time and Space on the Transverse Dimension*

Known human languages use both the sagittal and vertical dimensions to describe time, which can be reflected in spatio-temporal metaphoric language. However, apart from sign languages (Emmorey, 2001), known human languages generally do not use left-right space when describing time. A possible explanation might be that the body is symmetric left to right (Casasanto & Jasmin, 2012; Traugott, 1978). When the body is symmetric on certain dimensions, there is no preferred direction on that dimension. Despite the fact that the transverse dimension is not reflected in spatio-temporal metaphoric language (Radden, 2004), people still use the transverse dimension to think about time. A major factor that can affect people's temporal perception on the transverse dimension is cultural artifacts such as writing direction.

Studies which looked at languages with a left-to-right writing direction, have found that space and time are closely associated on the transverse dimension. For example, Santiago, Lupáñez, Pérez, and Funes (2007) and Santiago, Román, Ouellet, Rodríguez, and Pérez-Azor (2010) showed that native Spanish speakers associate left with the past, and right with the future. Studies have found that English speakers associate left with the past and earlier moments, and right with the future and later moments (Fuhrman & Boroditsky, 2010; Weger & Pratt, 2008). The left-to-right temporal direction was also found in Mandarin speakers from mainland China, French speakers (cf. Cooperrider, Núñez, & Sweetser, 2014), Italian speakers with normal sight (Maass & Russo, 2003) and blind Italian speakers (Bottini,

Crepaldi, Casasanto, Crollen, & Collignon, 2015).

Apart from studies that looked at languages that have a left-to-right writing, studies also looked at languages written from right to left. Tversky, Kugelmass, and Winter (1991) found that Arabic participants arrange a sequence of events from right to left. Another study indicates that people who speak Hebrew, another language with right-to-left writing, prefer to arrange temporal sequences from right to left, contrary to English speakers, who prefer to arrange temporal sequences from left to right (Fuhrman & Boroditsky, 2010).

Further evidence for the influence of writing direction on cross-cultural differences comes from studies on preliterate kindergarteners from languages that are written from left to right such as German and ones that are written from right to left such as Hebrew (Dobel, Diesendruck, & Bölte, 2007). They found that preliterate children do not show transversal directional preferences, unlike adult speakers. As we can see, studies that looked at how people associate time with transverse direction revealed that there is a close connection between transverse timeline and writing directions.

2.4 Spatio-Temporal Metaphors in English and Mandarin

Literature discussed in the previous section suggests that languages differ in how they use space to describe time (sagittal and vertical) and how they are written (transverse). In the current study, I will focus on two languages: English and Mandarin. The main reason for studying the two languages is that they have different dominant temporal directions on the sagittal dimension, and therefore speakers of the two languages can be compared when testing the effect of the processing temporal information on body movement patterns.

In terms of how time is understood, English and Mandarin have cross-dimensional and within-dimensional differences. On the sagittal dimension, as has been discussed, there are two types of temporal models: the Moving Ego model and the Moving Time model. In the Moving Ego model time is seen as a sequence of temporal events and the ego moves from the past towards later events. In the Moving Time model, temporal events move

through the ego. The two different temporal metaphors lead to different associations between time and directions (Boroditsky, 2000; Clark, 1973; Lakoff & Johnson, 1980/2003; McTaggart, 1908). As has been argued by Boroditsky (2000), in the Moving Ego model, front is associated with the future or a later event, whereas in the Moving Time model, front is associated with the past or an earlier event.

English and Mandarin appear to have different patterns of using the two types of temporal models. For instance, both the Moving Ego model and the Moving Time model are dominant in English, and studies found that English speakers associate front with the future and back with the past (Miles, Nind, & Macrae, 2010). On the contrary, although both the Moving Ego and Moving Time models exist in Mandarin, the Moving Time model (future-to-back) seems to be dominant (Yu, 1998). However, this claim is only based on linguistic data, and it lacks evidence from behavioural experiments (Yu, 2012), and studies that tried to look at it behaviorally failed to find any result (e.g., Fuhrman et al., 2011).

In terms of cross-dimensional differences, English uses the horizontal dimension and Mandarin uses both the horizontal and vertical dimensions. In terms of within-dimensional differences, as discussed, English and Mandarin also show different patterns on the sagittal dimension. English speakers associate front with the future, but Mandarin speakers with higher proficiencies in Mandarin are more likely to associate back with the future (Fuhrman et al., 2011).

The other reason for studying the two languages is that the potentially different temporal directions on the sagittal dimension between the two languages make them ideal to test the effect of language on body movement patterns when processing temporal information, which is one of the major research questions and will be discussed later. Moreover, only a few studies in the literature looked at the effect of language context on how ME bilinguals think about time and therefore the current study will be related to this issue. In the following sections I will talk about similarities and differences between English and Mandarin in terms of temporal directions, and the issue of comparative study on Mandarin and English speakers' mental representation of time.

2.4.1 The Relationship between Space and Time in English

English uses spatial words to describe time. As has been mentioned, English has the Moving Ego and Moving Time models (Boroditsky, 2000). Front is associated with the future and back is associated with the past in the Moving Ego model (Miles, Nind, & Macrae, 2010; Sell & Kaschak, 2011). In the Moving Time model, front is associated with an earlier moment and back is associated with a later moment. Many studies have provided evidence for the temporal direction in English.

English rarely uses spatio-temporal metaphoric language on the vertical dimension. Linguistic data from English expressions show contradictory directions on the vertical dimension. On the one hand, one can “pass down the knowledge” (Boroditsky, 2001), suggesting that the future is associated with down in English. On the other hand, Lakoff and Johnson (1980/2003) suggest that the future can also be associated with up in English because THE FUTURE WILL BE BETTER and UP IS GOOD. However, these two reasons have their own flaws. First, people are not always optimistic, which means that people do not usually think that the FUTURE is GOOD. Second, the future-down metaphor is not paired with past-up metaphor. Moreover, the word *up* itself sometimes may not have spatial meanings. If temporal meanings derive from spatial meanings, then why the word *up* is temporal when its original meaning may not be spatial? When testing vertical temporal directions, existing studies that tested English speakers on the vertical dimension (Boroditsky, 2001; Boroditsky et al., 2011; Miles et al., 2011) did not find any preferred vertical temporal direction from native English speakers.

Despite the fact that spatio-temporal metaphoric language in English do not involve talking about temporal information on the transverse dimension, studies found that English speakers do have a preferred left-to-right transversal temporal direction (Casasanto & Jasmin, 2012; Fuhrman et al., 2011). Moreover, the transverse mental time line is probably the most activated one during speech if we go by English speakers' spontaneous co-speech gestures (Casasanto & Jasmin, 2012).

2.4.2 *The Relationship between Space and Time in Mandarin*

Spatio-temporal metaphors in Mandarin involve two dimensions. First, Mandarin uses the sagittal dimension, which can be revealed by the Moving Ego and Moving Time models in Mandarin. Second, Mandarin also uses the vertical dimensions to talk about time, as is suggested by spatio-temporal metaphoric language such as *shang-ge yue* (*upper month* - last month). Spatio-temporal metaphoric language in Mandarin do not involve using left and right; however, Mandarin speakers have temporal directions on the transverse dimension that are caused by the writing directions.

If anyone who can speak Mandarin were to check the meaning of *qian* (before/front/ahead) and *hou* (after/behind/back) in the dictionary, he/she would find that the two lexical items are used almost symmetrically on the sagittal dimension when temporal information is described. When talking about time, *hou* is used mostly for the future, and *qian* is mostly used for the past. However, *hou* can also be used for the past. For example, the word *hou* (meaning back) as in *wanghoukan*, which means to look back to the past (Yu, 2012), indicates that the back can also be associated with the past. Thus, both front and back can be associated with both the future and the past in Mandarin. The current study tested Mandarin speakers to try and find out if front-to-past and back-to-future provide the dominant temporal sequence on the sagittal dimension in Mandarin.

Alverson (1994) claimed that the major difference between English and Mandarin was that in English the front is associated with the future, whereas in Mandarin the back is associated with the future. Mandarin expressions such as *yi qian* (front) and *yi hou* (back), which mean 'in the past' or 'before now' and 'in the future' or 'after now' respectively, can be seen as evidence for this view. However, Yu (2012) suggested that despite this, the overall sagittal temporal direction in Mandarin is consistent with the one in English that is suggested by Lakoff (1993). Yu (2012) argued that in Mandarin the future is a journey or a road that is in front of a person and the past is a journey left behind, and his analysis was supported by Mandarin linguistic data such as in words *zhan wang* (literal meaning forward-gaze into distance) and *hui gu* (literal meaning turn around-look), which mean 'look into the future'

and ‘review’ respectively. Evidence supporting Yu's (2012) claim about the direction of time in Chinese can even be found in ancient poems by famous poets such as Du Fu, Gao Shi and Su Shi in the Tang and Song Dynasties, which suggests that in ancient China, Chinese people were already using the Moving Ego model with future-to-front and past-to-back associations.

When comparing Alverson's (1994) interpretation with his, Yu (1998) argued that the apparent contradiction between *qian tian* (*front/before day* means ‘the day before yesterday’) and *qian tu* (*front road* means ‘prospect’) is due to the existence of both the Moving Ego and Moving Time models in Mandarin. *Qian tu* (literal meaning front road), which means prospect, is based on the Moving Ego model, in which a person is facing the future; whereas *qian tian* (the day before yesterday) is based on the Moving Time model since the word *qian tian* is a shortened form of *zuo tian de qian yi tian* (the day that is ahead of yesterday). In the Moving Time model, days can be seen as a moving train, so *the day before yesterday* is *ahead of yesterday*. In contrast to Yu (1998), Ahrens and Huang (2002) proposed that the Moving Ego model does not exist in Mandarin; instead, the ego faces the past when standing still, but faces the future when being attached to a time point and moving along with the point. Yu (1998) and Ahrens and Huang (2002) agreed however, that the dominant representation of time in Mandarin is the Moving Time model, in which earlier moments (or the past) are associated with front, and later moments (or the future) are associated with back (Yu, 2012). Literature which mentioned sagittal temporal direction in Mandarin was only based on linguistic data. In fact, sagittal temporal direction in Mandarin is almost never confirmed. Nevertheless, some studies (Fuhrman et al., 2011; Lai & Boroditsky, 2013) found that there was a significant effect of language proficiency in Mandarin on how likely it was for ME bilinguals to tend to associate the future with back. In other words, bilinguals with higher Mandarin proficiencies are more likely to use the Moving Time metaphor than bilinguals with lower Mandarin proficiencies.

It has been argued that the association between front and the past in Mandarin is different from that in the Aymara language (Evans, 2003). In Mandarin, front is associated with the past because earlier events are associated with front in the Moving Time model. Therefore, the Moving Time

model in Mandarin is similar to that in English. On the contrary, in the Aymara language, front is associated with the past because the past can be seen, which is based on visual content.

On the vertical dimension, up is associated with the past in Mandarin as in *shang-ge yue* (literal meaning upper month), which means last month; and down is associated with the future as in *xia-ge yue* (literal meaning lower month), which means next month. Studies based on behavioural experiments suggest that Mandarin speakers are more likely to think about time vertically than English speakers (Boroditsky et al., 2011). On the transverse dimension, Mandarin speakers from mainland China have been found to associate left with the past and right with the future (Kong & You, 2012).

2.4.3 *An Alternative View of Spatio-Temporal Metaphors in Mandarin*

Most studies on spatio-temporal metaphoric language follow Lakoff's (1993) cognitive linguistic view, which described the two types of temporal model: the Moving Ego and Moving Time models. The two models are based on the TIME IS MOTION metaphor and therefore are called Dynamic Models. However, some other studies suggested that these dynamic models may not be able to explain some linguistic data of temporal expressions because temporal events do not seem to move in these expressions as in *the class meetings are too close together* (Núñez & Sweetser, 2006). As a result, a Static Model is used to explain this type of data.

According to Static Models, some temporal expressions that show no motion can also be explained by Static Models. For example, in the Mandarin phrase *qiantian* (front day - the day before yesterday), the observer faces the past and the present is the reference point (Chen, 2014). According to Chen (2014), many Mandarin expressions that show no motion and belong to the Moving Time model (front-earlier) can also be explained by Static Models. Moreover, in these static models, the observer always faces the past.

Regardless of dynamic or static models, front is mostly associated with earlier events or the past in Mandarin. As we can see, English and Mandarin have different temporal directions on the sagittal dimension. This potential difference on the sagittal dimension allowed the current study to test the

potential different effects of the processing of temporal information on body movements between speakers of the two languages. However, before testing the effect of different temporal directions on body movements, it was necessary to first test whether Mandarin speakers actually think that the future (or later event) is behind, which is suggested by the Moving Time model. Therefore, one purpose of the first experiment was to serve as a pilot study.

2.5 The Issue of Comparative Analyses between Mandarin and English Speakers on Temporal Perception

The unusual way of encoding time in Mandarin was documented as early as last century (e.g., Scott, 1989). Such a phenomenon is interesting because probably Mandarin is the language that uses vertical temporal expressions more often than any other known human languages. It has also begun to attract people's attention in the last few years since a new study paid attention to the different ways of encoding time between English and Mandarin, and combined the difference with linguistic relativity (Boroditsky, 2001). In the rest of the section, I will first briefly talk about linguistic relativity and then focus on the issue of recent comparative analyses on how English and Mandarin speakers think about time.

2.5.1 Linguistic Relativity

Are our own concepts of 'time', 'space,' and 'matter' given in substantially the same form by experience to all men, or are they in part conditioned by the structure of particular languages (Whorf, 1941, p.78)?

The famous Sapir-Whorf hypothesis (Carroll, 1956) states that language can affect people's non-linguistic cognition. Although the strong version of the Sapir-Whorf hypothesis, that a language determines thought as linguistic determinism is long abandoned, a weak version of the hypothesis is more readily accepted: the properties of a given language could affect how speakers conceptualize the world, and this effect can be extended to non-linguistic cognitive behaviors. This version of the hypothesis is also known as linguistic relativity. Based on the quotation that has been used (Whorf, 1941), we can

see that the concept ‘time’ in fact can be a good example of studying linguistic relativity.

The idea that each language community has its own way of perceiving the world (Carroll, 1956) was stated by Benjamin Lee Whorf, who followed the work of his teacher, Edward Sapir. However, neither of them formulated testable hypotheses (Kay & Kempton, 1984). Brown (1976) summarized their ideas and said that linguistic relativity can be summarized as the following two hypotheses:

1. If two language systems have structural differences between them, the structural differences will lead speakers of the two languages to have non-linguistic cognitive differences.
2. The structure of your first language will have a strong influence on your way of perceiving the world.

Later on, Whorf's followers formulated a third hypothesis which is based on the first two (Kay & Kempton, 1984).

3. The semantic systems of different languages can be different in many ways.

Most empirical evidence collected for hypotheses 1 and 3 suggests that people who speak different languages conceptualize the world in different ways. Various experimental tasks testing cross-linguistic differences have been conducted to test the effect of language on the perception of the understanding of certain concepts such as colour (Kay & Kempton, 1984; Lucy & Shweder, 1979; Winawer et al., 2007), the ability of counterfactual thinking (Au, 1983), the categorization of objects (Bross & Pfaller, 2012; Saalbach & Imai, 2007; Zhang & Schmitt, 1998), grammatical gender (Sera, Berge, & del Castillo Pintado, 1994), conceptual development in children (Markman & Hutchinson, 1984), spatial thinking (Bowerman, 1996), temporal perception (Chen, Su, & O’Searghdha, 2013) and the effect of spatial information on temporal judgments (Casasanto et al., 2004).

As has been mentioned, the weaker version of Sapir-Whorf's hypothesis has attracted considerable attention in the last few decades. I will not recount the long history of debate on the theory, and what is of interest here is that many existing studies that I have mentioned have looked at the different cognitive behaviours between speakers of languages that could be caused by different language structures. Some of them did indeed find some cognitive differences, for example, that spatial information has different effects on Greek and English speakers when giving temporal judgments (Casasanto, 2008); whereas some others did not (Au, 1983). For example, Bloom (cf. Au, 1983) found that Chinese speakers are less likely to understand a counterfactual story than English speakers because Chinese does not have a counterfactual marker like English. However, Au (1983) replicated the experiment and found that Chinese speakers with no experience in English still performed well as long as the story was in idiomatic Chinese. Such a problem is also the reason for linguistic relativity being criticized and falsified: people who expressed doubts about linguistic relativity did not attack the theory in principle but questioned the method and the data (Casasanto, 2008). Since linguistic relativity hypothesized that cognitive differences caused by different language structures should be observed in non-linguistic behaviour, using only linguistic data to support linguistic relativity will lead to a circular argument. However, linguistic data is still often useful for observing potential differences between languages and forming hypotheses.

2.5.2 The Issue of Linguistic Relativity in Spatio-temporal Metaphors

Studies in some areas have found evidence for linguistic relativity. For example, Winawer et al. (2007) found that Russian speakers are quicker to distinguish the difference between dark blue and light blue than English speakers, which is because the two colours are encoded separately in different words in Russian. However, studies on the perception of time and spatio-temporal metaphors across languages, especially between Mandarin and English, show less clear results. For example, as has been mentioned, Boroditsky (2001) used a behavioural experiment that contained both linguistic material and sequential pictures. She found that English speakers are not affected by

vertical primes (pictures) and ME bilinguals are affected by vertical primes even processing English sentences, and she claimed that such a non-language-specific effect can be seen as strong evidence of linguistic relativity. However, several studies tried to replicate the experiment (e.g., Chen, 2007), and they were unable to replicate the result. Chen and O'Seaghdha (2013) criticized Boroditsky (2001) for confusing the non-language-specific and non-linguistic concepts and further raised the issue of using linguistic tasks to test linguistic relativity. To a large extent they were right about the issue. Until more sophisticated experimental methodology can be found, it would still be difficult to test the perception of time from the point of view of linguistic relativity.

Instead of using linguistic materials, some other studies (Miles et al., 2011) used cultural figures to establish experimental conditions, such as using photos of Jet Li and Brad Pitt. They found that bilinguals arranged sequential photos to different directions in different cultural contexts. However, such studies can only reveal cross-cultural differences, but not Whorfian effects, since there would be no way to clearly attribute cross-cultural differences to patterns in languages either (Hendricks & Boroditsky, 2015). More recent comparative analyses between English and Mandarin showed some evidence of linguistic relativity. For example, Boroditsky et al. (2011), Fuhrman et al. (2011) and Miles et al. (2011) conducted comparative analyses between English and Mandarin speakers by using non-linguistic tasks and found cross-group differences. Their studies revealed the effect of language context on ME bilinguals on how they might perceive time differently, and how experience of one language could affect bilinguals' temporal perception in the other language.

In order to test the effect of language on how Mandarin-English (ME) bilinguals use the two types of temporal metaphors, Lai and Boroditsky (2013) tested bilingual and monolingual speakers of Mandarin and English on their understanding of ambiguous questions in different languages and found that bilinguals in the English condition were more likely to adopt the Moving Time model than English monolinguals, whereas bilinguals in the Mandarin condition were less likely to adopt the Moving Time model than Mandarin monolinguals. This result reveals the effect of language on the perception of temporal metaphors. Their results also show that bilinguals'

Mandarin proficiencies have significant effects on the likelihood of using the Moving Time model: the higher their Mandarin proficiencies are, the more likely they are to use the Moving Time model. The findings from Lai and Boroditsky (2013) are consistent with those from Fuhrman et al. (2011) who found that, in an explicit task, when comparing speakers with different levels of proficiency in Mandarin, the participants who were more proficient in Mandarin were more likely to associate the future with back, which is the direction of the Moving Time model. Such studies also highlighted an important methodological consideration: in order to study an effect of cross-domain mapping, one needs to compare speakers of different languages that might have different cross-domain mappings such as English (future-to-front as the Moving Ego metaphor) and Mandarin (future-to-back as the Moving Time metaphor); moreover, bilingual speakers of the two languages are perfect testing subjects for testing cross-linguistic effects. This is why late ME bilinguals were tested in the current study since Mandarin proficiency is closely related to how likely it is that ME bilinguals would use the Moving Time model (back-to-future). By testing late ME bilinguals, it is more likely that different temporal directions would be observed on the sagittal dimension between English monolinguals and the bilinguals.

In the current study, I test how language shapes the way late bilinguals associate time with space that is revealed by different body movement patterns in different languages. This tests the effect of language on cognition that is revealed by body movements.

2.6 The First Research Question

As we can see, studies show that English and Mandarin have different ways to encode time on the sagittal and the vertical dimensions. Within each of the two dimensions, time might have different directions in the two languages. Before testing the effect of temporal direction on body movements, it was necessary to test whether Mandarin speakers would associate the future with back and past with front. Based on the findings in the literature, the first research question is:

1. How do English and Mandarin speakers and bilinguals of the two lan-

guages associate time with direction on each dimension?

This question will be answered by dividing it into several small questions, such as:

- (a) Do native English speakers and native Mandarin speakers have different mental timelines on the sagittal and the vertical dimensions? In other words, will English speakers associate front and up with the future and back and down with the past, and will Mandarin speakers associate back and down with the future and front and up with the past?
- (b) If there are differences, will bilinguals associate front with the future and back with the past when speaking English or perceiving temporal information in English?

Importantly, the current study will compare bilingual speakers of the two languages in different language conditions, and then compare them with monolingual speakers to see if they behave differently. Existing studies (e.g., Boroditsky, 2001; Boroditsky et al., 2011; Fuhrman et al., 2011) conducted only on bilinguals assumed that bilinguals in either language condition might behave like monolinguals of the same language. However, if there are cross-linguistic effects, bilinguals in either language context could behave differently from monolinguals of the same language. For instance, bilinguals' perception of temporal information in the Mandarin condition could be different from that of Mandarin monolinguals because they are affected by the fact that they can speak English.

In order to answer these questions, the first experiment was designed and tested on the monolingual and the bilingual speakers of the two languages, and will be presented in Chapter 3. As discussed, one main aim of the first experiment was to serve as a pilot study for the second experiment. Some results on the sagittal dimension will be used to form hypotheses for the second experiment, which was to test people's body movement patterns. In the next sections, I will discuss how spatio-temporal metaphor and temporal information are expressed in gesture. This will be related to the methodology of the first experiment. After that, I will talk about the relationship between

the processing of temporal information and body movements, which will lead us to my second experiment and its methodology.

2.7 *Gesture Study and Temporal Gesture*

This section will first provide a definition of gestures and discuss the importance of testing gesture in studying conceptual metaphor and cognition. After giving an overview of gesture types, I will focus on metaphoric gestures and deictic gestures and especially temporal gestures, which are the types most relevant to the current study. The insights from this section form the foundation of the methodology.

2.7.1 The Definition of Gesture

Gesture can refer to any wilful body movements (Cienki, 2008). In a broad sense, it means that gestures are body movements that have communicative intent. Studies on gesturing mostly focus on the hands and the arms. Since the current study looks at people's mental representation of time from an embodied point of view and gestures that describe time in space mostly involve the hands, I will only consider hand gestures here.

A hand gesture can have different components. According to Kendon (1980, 2004) a gesture phrase is a unit of visible body movement that is meaningful. A gesture phrase consists of three phases: preparation, stroke and recovery (Kendon, 2004) or retraction (McNeill, 1992). The stroke phase is the part of a gesture that contains its main content (McNeill, 1992). Since the stroke phase is considered to minimally constitute a gesture (Kendon, 2004), studies on the stroke phase have become the central interest in the study of metaphor and gesture (Cienki & Müller, 2008). The preparation phase is that which leads up to the stroke phase (Kendon, 2004). In the recovery or retraction phase, which follows the stroke phase, the hand moves to a relaxed position that may not necessarily be the position where the preparation phase started. The recovery phase is optional since the hand might perform another gesture right after the first one.

2.7.2 The Connection between Gesture and Speech Production

Studying people's gestures is as important as studying verbal language. Speakers of different languages gesture differently in ways that are consistent with specific cognitive patterns in corresponding languages (McNeill & Duncan, 2000). Gestures are also consistent with conceptual metaphor and language (Cienki & Müller, 2008). When people use metaphors to describe abstract ideas, we can use gesture to provide additional information that is absent in verbal speech. We can also use gestures to express concrete physical actions in a different manner from verbal utterances. Despite the fact that gestures and spoken language are different, they both belong to the same single underlying process (Kendon, 1980, 2004; McNeill, 1992, 2005). Interestingly, gestures and speech adopt different ways of expressing meanings, but at the same time they cooperate with each other and reflect the same cognitive processes. Gestures and speech are so interdependent; one should always look at both of them when trying to analyze utterance production and cognition (Alibali, Bassok, Solomon, Syc, & Goldin-Meadow, 1999).

2.7.3 Conceptual Metaphor, Embodied Cognition and Gesture

From an embodied point of view, studying gesture provides us with a picture of how people conceptualize things from a different angle. It has been argued that gestures are perceptual and motor simulations that are essential to embodied language and mental imagery (Hostetter & Alibali, 2008). Gesturing has more freedom than verbal speech that has syntactic, phonological, phonetic and morphological constraints; however, that does not mean there are no constraints on gestures. From an analytical point of view, in order to study gesture one needs to identify gestures, and if a gesture is identifiable, it will usually have three phases, and it needs to have at least a stroke phase (Cienki, 2008). From the point of view of linguistic relativity, gestures can be affected by language-specific cognitive patterns. In terms of conceptual metaphor, CMT creates the foundation for embodied metaphor, and it states that abstract concepts in language are represented in concrete domains (Lakoff, 1987). Under this view, gesture can provide important non-linguistic evidence for studying metaphorical thinking (Chui, 2011; Cienki,

2008; Lakoff & Johnson, 1980/2003; Langacker, 2008; Müller, 2008); if conceptual metaphor is grounded in physical experience, we should be able to see it from gestures (Chui, 2011). Gestures are affected by both cognition and language. For example, co-speech gestures occur during spontaneous speech, and each language has its own language-specific gesturing pattern (Núñez & Sweetser, 2006).

2.7.4 *Gesticulation*

This study will only talk about one type of gesture, which is gesticulation. Gesticulation refers to idiosyncratic spontaneous movements of the hands and the arms that accompany speech. It is a major focus in gesture studies by McNeill (Kendon, 2004) and others who study cognition, because this type of co-speech gesture can reveal the utterance's primitive stage (McNeill, 1992). It is believed that co-speech gestures or gesticulation can provide information about cognitive processes since they are produced subconsciously. Gesticulation does not have fixed meanings, as it can be performed alongside any part of verbal speech; however, this type of gesture can also reflect the speaker's thoughts and mental images on particular topics. McNeill and Duncan (2000) have also argued that gesticulation can provide mental content in real time. People use gestures when talking about spatial information (Allen, 2003; Alibali, 2005), and also use hand gestures when talking about temporal information (Casasanto & Jasmin, 2012).

According to McNeill (1992), spontaneous gestures can be divided into four types (Cienki, 2008), which are not mutually exclusive, since a gesture can belong to more than one type of gesticulation. The four types of spontaneous gestures are beats, iconics, deictics, and metaphors. The last two are most relevant to the current study, and will therefore be discussed in more detail.

Beats are rhythmic gestures that mark words or phrases as significant by rapidly using fingers or hands without discernible meanings. They are small, rapid and easily recognizable.

Iconics are gestures that depict the semantic content of the sentence, such as an object and an action.

Deictic gestures are pointing gestures performed with fingers or the arm, which usually aim at concrete space. For example, people use fingers to point in different directions. However, deictic gestures can also point to conceptual space. As has been discussed, English speakers use hands to point left and right to indicate the past and the future respectively. People who speak the Aymara language point forward for the past and point backward for the future. Deictic gestures need to be accompanied by speech to clarify their meanings.

Metaphoric gestures depict an image but a metaphoric gesture represents an abstract idea rather than a physical entity. Therefore, whether a gesture is iconic or metaphoric depends on the verbal speech. For example, holding out one's hands with the palms facing each other in front of one's body could be an iconic gesture if the speaker is describing an object, but it could also be metaphoric if the speaker is asking a question, since the speaker is sending a package of information as in the conduit metaphor. The categories of gesticulation are not mutually exclusive. Gestures relating to the focus of the current study, spatio-temporal metaphor, can be both deictic and metaphoric. A gesture that is performed when people produce temporal information is deictic, since people use their hands and point into space. However, when physical direction is associated with temporal information, the gesture becomes metaphorical.

As discussed, one criticism levelled at CMT was circularity of argumentation (Murphy, 1996, 1997). It was argued that conventional metaphors have been lexicalized and therefore a cross-domain mapping is no longer necessary (Glucksberg, 2001). Metaphoric gestures are especially important since they provide non-linguistic evidence for conceptual metaphor, and thus complement evidence from other fields of study such as behaviour studies and brain imaging (Lakoff & Johnson, 1980/2003). Metaphoric gestures can provide information about cognitive processes and the mental representations of concepts that cannot be easily found in speech. Such evidence has been recently tested in a detailed study of a Mandarin speaker's co-speech metaphoric gestures (Chui, 2011) for metaphors such as TIME IS SPACE. Chui (2011) found that when the Mandarin speaker talked about the past, he pointed backwards; but when he said *zhiqian* (before now), he pointed forward be-

cause the word has *qian* (front) in it. The study suggests that conventional metaphors are not lexicalized and specific lexical items can affect how people conceptualize certain ideas. It is also worth mentioning that, although the spatial information in temporal words can affect how people perceive time, Chui's study was only based on an observation from a short conversation. In the current study, I will test whether such an effect exists in a wider range of participants. We can see that gestures can thus be used as evidence for CMT and as a tool for studying the underlying cognitive mechanism behind conceptual metaphors.

2.7.5 Temporal Gestures

Gestures that are used to describe time such as things that happened in the past, the present or an upcoming event, sequential relationships between different moments, and temporal length, that is duration, are called temporal gestures. Temporal gestures are metaphoric because they are based on cognitive mapping between time and space. They are also deictic since people need to point to space when giving temporal information. Temporal gestures are gesticulation. They need to be accompanied by speech so that the gesturing can make sense.

From an embodied view, temporal gestures are evidential examples that reflect perceptual simulation in embodied language and mental imagery of representation of time. Many human languages and cultures use temporal gestures. However, despite the universal phenomenon of using gesture to describe temporal information, there are also differences between languages and cultures. Based on the universal use of spatial gesture when describing time, Núñez and Cooperrider (2013) divided languages that have already been studied on their spatio-temporal metaphors into two categories: cultures with high levels of literacy and cultures with low levels of literacy. Most languages in the former group such as English, Greek, Mandarin, Hebrew and Spanish associate time with egocentric directions; whereas cultures in the latter group tend to use either absolute directions to describe time, such as Pormpuraaw (Boroditsky & Gaby, 2010) and Yupno (Núñez, Cooperrider, Doan, & Wassmann, 2012), or mixed models of egocentric and absolute

directions, such as the Aymara language (Núñez & Sweetser, 2006).

Existing studies have found that how people produce temporal gestures was mostly consistent with how time is described in a language and how the language is written. Mandarin speakers used gestures on the sagittal and the vertical dimensions, such as using the hand to point to their back and front to indicate the past and an earlier event respectively, and they also raised their hands to indicate the past (Chui, 2011). Mandarin-English bilinguals' vertical gestures were found to be produced more often when talking about time in Mandarin than in English (Gu, Mol, Hoetjes, & Swerts, 2013, 2014). For English, studies have found that speakers of English produce gestures on the transverse dimension when talking about the past and the future, even though English spatio-temporal metaphoric language associates time with space on the sagittal dimension (Casasanto & Jasmin, 2012; Cienki, 1998). Casasanto and Jasmin (2012) also found that English speakers were more likely to use the transverse dimension for spontaneous gestures, whereas the sagittal dimension was more likely to be used for elicited gestures. In studies of languages that use absolute directions to perceive time, speakers of Yupno associate the past with downhill and the future with uphill (Núñez et al., 2012), whereas in Pormpuraaw the past is associated with east and the future is associated with west (Boroditsky & Gaby, 2010). In Aymara the past is associated with front and the future is associated with one's back, and, the past is also associated with east and the future is associated with west, which reflects a mixed model of absolute and egocentric systems (Núñez & Cornejo, 2012).

To summarize, studies on different languages show that co-speech gestures can reveal the mental representations of time, and thus provide evidence that both gesture and language are from the same cognitive origin (Kita & Özyürek, 2003). Importantly, mental representations of conceptualized time appear to be shaped by several factors such as languages, writing directions, spatial metaphors (absolute vs. egocentric), geographic features of the habitat and spatio-temporal metaphoric language. As mentioned, the first research question of the current study looks at how monolinguals and bilinguals of English and Mandarin associate time with directions differently within each dimension. In order to address this question, the first experiment

tests people's temporal gestures, since they can reveal how people associate time with space on different physical dimensions.

2.7.6 Explicit Tasks vs. Implicit Tasks

The first experiment was a pointing task. Each participant was given a list of words and they needed to point a direction for each word. This approach is considered to be an explicit task because it asks people's opinions directly. This methodology has been used several times in the literature of studying space-time mental representations. However, studies that conducted this explicit task also often adopted some implicit tasks in order to make sure their studies can truly reveal people's mental representations of time. For example, Fuhrman et al. (2011) used both the explicit task and an implicit task to test ME bilinguals' mental representations of time. Implicit tasks often tested compatibility effects between space and time. For example, if the future and right are closely related as in people's mental representations of time, then people should respond faster when the future and right are presented together than when the future and left are presented together. An explicit task might reveal people's potential opinions or preferences towards certain ideas, whereas implicit tasks are considered to be able to reveal true implicit associations.

Existing studies that have conducted research on temporal metaphors and how people process temporal information used both explicit and implicit tasks. The purpose of an explicit task is to collect people's attitudes towards certain ideas or concepts by directly asking them related questions, whereas an implicit task tests people's implicit associations between concepts or ideas, such as attitudes and preferences. Explicit tasks and implicit tasks can reveal different results. For example, Steffens (2005) tested people's attitudes towards lesbians and gay men by using both explicit questions and implicit tasks. Results from the study revealed that although answers to explicit questions showed that the participants had a very positive attitude towards lesbians and gay men, results from the implicit tasks were relatively negative. Despite this, in some contexts, explicit measures can also show similar results to implicit tasks. McConnell and Leibold (2001) used both explicit measures

and implicit tasks to test racial prejudice, and they found that people who have a stronger negative attitude towards black in the implicit test also had more negative prejudices towards black in explicit measures.

The second experiment tested people's body movement during processing temporal information, and such an approach is considered to be an implicit task because it did not ask how people associate time with directions directly.

2.8 Processing Temporal Information in Body Movements

In the last few years, the connection between processing time-related information and part/whole body motion has begun to attract people's attention. The mechanism behind this phenomenon is the metaphorical mapping between abstract concept and space and our sensory-motor patterns (Barsalou, 2008; Boroditsky, 2000; Gallese & Lakoff, 2005; Hartmann & Mast, 2012; Lakoff & Johnson, 1980/2003). Empirical evidence from both clinical neuropsychology and cognitive linguistics suggests that imagining and perceiving an action will activate the same region in the brain as if one is physically performing the actual action (Glenberg et al., 2008; Pulvermüller, 2005; Tetamanti et al., 2005), in other words, “imagination, like perceiving and doing, is embodied” (Gallese & Lakoff, 2005, p.456).

The embodied point of view suggests shared mechanisms for the processing of temporal information and spatial body movements, which are similar to mechanisms linking the processing of action words and overt motor action (Hartmann & Mast, 2012). Walsh (2003) suggests that the inferior parietal cortex is responsible for perceiving space and controlling action in space and the area is also involved in perceiving time, suggesting that bodily actions may play an important role in grounding the understanding of spatio-temporal concepts. The relationship between bodily action and the processing of temporal information was tested with experiments that elicited movements of the hand or the arm and provided empirical evidence for a close connection between processing temporal information and arm movement. Miles, Betka, et al. (2010) conducted an experiment and asked native English speakers to use a mouse to categorize past words and future words. The participants needed to click on “START” in order to see the word and

then clicked on either “PAST” or “FUTURE” to categorize each word. They found that people's mouse movement trajectories were different during the compatible condition (PAST on the left) and in the incompatible condition (FUTURE on the left), which suggests that people's actions reflect a mental time line that is formed by the writing direction in the social and cultural conventions. The study also raised an important question: if arm movements can reflect the mental time line on the transverse dimension, then certain actions should also reflect the mental time line on the sagittal dimension. To explore this hypothesis, several studies tested people's arm movements on the sagittal axis (Koch et al., 2011; Sell & Kaschak, 2011; Ulrich et al., 2012). For example, Sell and Kaschak (2011) tested whether the effects of sentences about the past and the future were compatible with the execution of certain arm movements: that is, sentences about the future should facilitate the execution of arm movements out to the front of the body, whereas sentences about the past should facilitate arm movement toward the body from the front. Their results supported their hypotheses.

Whole body movements during perceiving temporal information have also been tested. Miles, Nind, and Macrae (2010) asked native English speakers to recall memories from the past and imagine their lives in the future while tracking their body movements. They used a tracking device that was attached to the participants' knees, and recorded a fifteen second window of moving trajectories. They found that people swayed backward up to 4 millimeters when thinking about the past, and they swayed forward up to 4 millimeters when thinking about the future. Their study suggests that real-time cognitive processing of temporal information can be revealed in action. However, can perceiving body movements make people think about the past and the future? Miles, Karpinska, et al. (2010) asked the participants to watch an animated star-field display with a black background. The participants were more likely to report having day dreams about the past when they saw the stars moving to the centre of the display, that is, backward movement, and they were more likely to report having day dreams about the future when they saw the stars starting out in the centre and moving away from the centre of the display, that is, forward movement. These studies together suggest there is a bidirectional effect between spatio-temporal

information and body (or perceived) movements. Studies also tested the effect of passive whole-body motion on the perception of temporal information (Hartmann & Mast, 2012) and numerical information (Hartmann, Grabherr, & Mast, 2012), and the findings suggest that even passive whole-body motion can affect the processing of mental time lines.

Although some studies (Miles, Nind, & Macrae, 2010) found a link between temporal perception and body movements, some other studies have tried to replicate the results but failed. For example Stins, Habets, Jongeling, and Cañal-Bruland (2016) tested the center of pressure when the participants were standing on a platform that is sensitive to the distribution of weight; however, the participants did not perform differently between when thinking about the past and when thinking about the future. In fact, both studies (e.g., Miles, Nind, & Macrae, 2010; Stins et al., 2016) reveal the same problem of only testing body posture when people were thinking, without knowing if the participants were really thinking about what was required by the experiments.

So far there are still unanswered questions regarding the relationship between the processing of temporal information and body movements. For example, when testing the effect of temporal information on motor responses, part-body motion such as movements of the arm has been tested by using the front space. Both whole body motion (in the responses and in the stimuli) and part-body motion are used by previous studies to test a compatibility effect of future-front and past-back associations. Languages that have a potentially reverse temporal direction such as Mandarin, which has the Moving Time model as its dominant temporal sequence, have not been tested on the sagittal dimension. Therefore, it is unknown whether the known effect of thinking about past/future on body-sway and future-away/past-near arm movements are caused by the mental representation of time in the corresponding language or whether it has something more general to do with the nature of moving direction for humans. In other words, since we always generally move forward to do things, we might sway more forward for the future than for the past no matter what language we speak. However, if the mental representations of time indeed can affect people's body motion, then people who speak a language that has a reverse temporal direction (or has

the Moving Time model as dominant) would probably sway more forward for the past than for the future. The current study will address this question by testing two languages that could have opposite sagittal temporal directions: English and Mandarin. The last question is that, as discussed, what participants think about in the experiment needs to be fully controlled. The current study will address these issues.

2.9 The Second Research Question

Regarding the connection between the perception of time and body movements, the current study will address a second question, which is:

2. If English and Mandarin have different temporal directions on the sagittal dimension, do monolinguals and bilinguals of the two languages have different body sway patterns during the processing of temporal information about the past and the future?

In order to answer this question, I will need to answer the following specific questions:

- (a) Do native English speakers sway their bodies according to the temporal direction in English during the perception and the production of temporal information in English?
- (b) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in Mandarin during the perception and the production of temporal information in Mandarin?
- (c) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in English or in Mandarin during the perception and the production of temporal information in English?

In order to answer these questions, the second experiment was designed and will be presented in Chapter 4. The second experiment looks at body movement patterns from Mandarin-English bilingual speakers and compares them with English speakers. If bilinguals show similar body movement patterns in

the English context to English speakers, it would seem to suggest that knowledge of English could affect their mental representation of time; however, if Mandarin speakers show different body movement directions from English speakers, it would suggest that the persistence of impact from Mandarin is stronger than the effect of the second language, which is English.

Studies of the bidirectional influences between the mental representations of time and body motion have used a range of different methodologies, such as tracking body motion trajectories (part versus whole), comparison of reaction times (RTs) between congruent condition and incongruent conditions, and self-reporting. Except for self-reporting, all of these methodologies involve some kind of implicit tasks. Testing reaction times is no doubt an implicit way of testing potential associations between factors. Body motion (partially and whole) might not be regarded as an implicit way of testing potential associations in a traditional sense. However, moving trajectories can reveal real-time cognitive activities and therefore comparison of trajectories can reveal potential cognitive differences. When temporal information is embedded in stimuli, participants pay attention to the task, but not to the temporal information, so testing body movement trajectories is one way to probe implicit associations.

The current study embeds temporal information in short stories, and asks participants to remember the content of the stories, and it was hoped to make participants pay more attention to the task. The other improvement in the current study is the use of auditory stimuli. Experiments that test the effect of processing temporal information on motor responses often use visual stimuli: that is, reading sentences on a computer screen, which also led to the problem of using only the space in front of people in eliciting responses. The current experiment uses auditory stimuli, and participants need to be listening to the stories while standing, so participants can use the whole 3D space around them. Miles, Nind, and Macrae (2010) tracked people's body motion in 3D space when people were thinking about the past and the future. The current study is going to replicate their results, and I will also test bilingual speakers' body movements in different language contexts when they speak and when they listen to stimuli that contain temporal information since body-sway during the perception and production of tem-

poral information has not been studied yet, although it has been found that conceptual metaphors play an important role in speech production (Sato, Schafer, & Bergen, 2015). If participants' body movement patterns are consistent with spatio-temporal metaphors during perception and production, it would be strong evidence supporting the idea that not only does understanding metaphorical expressions involve activating the body (Gibbs, 2013), but motion still plays an important role in producing temporal information.

One reason for comparing trajectories between the future and the past rather than measuring absolute moving distance has to do with the fact that body motion is subtle, and it is hard to know people's neutral position (see Chapter 4 for more discussion). If we look at existing studies that tested body motion trajectories (tracking moving distance rather than testing the centre of gravity), we can see that the maximum moving distance in a 15 seconds observation was only 4 millimetres in each direction (Miles, Nind, & Macrae, 2010). Another reason is that, as has been discussed previously, a gesture is generally divided into several components for analysis, in order to see the mechanism of the expression of the meaning, and the stroke phase is the part that conveys most of the meaning. However, such an approach is not suitable for analyzing spontaneous body-sway because it is almost impossible to separate a stroke phase from a preparation phase. A body motion could be either the recovery phase for the previous body-sway or the preparation phase for its following body-sway. Therefore, body sway patterns cannot be analyzed as gestures.

In the tradition of analysing gestures, the whole experiment is usually videotaped and then coded by an experimenter afterwards. That means only body movements that are visible to the human eye can be noticed and analysed. A coder needs to go through training to establish reliable coding strategies, but since participants can be different from one another, a particular coding strategy, such as deciding which part of a movement is interesting to analyse and which phase it belonged to, may work for one person but not for someone else (Eapen, Baron, Street, & Richardson, 2010). Therefore, the current study used a tracking device and recorded every body movement accurately, and not only is such an approach objective compared with subjective decisions (Eapen et al., 2010), but is more informative. More

importantly, it is difficult and almost impossible to collect people's absolute moving directions, and therefore, simpler questions are asked; such as whether participants sway more forward for the future than for the past, or whether they sway more backward for the future than for the past.

The connection between the processing of temporal information and body movements not only forms an important methodological foundation for the current study, but it can also help answer our first research question, such as whether a mental time line is transferable when speaking a different language, because testing body movement trajectories is testing an implicit association.

Mandarin monolinguals were not tested in the body sway experiment because the tracking system is located in the University of Canterbury, and for practical reasons it is almost impossible to find Mandarin monolingual speakers in the region who are in the same age range as the other groups. However, it would have been good to have had them.

In the next section, I will talk about the relationship between perceived body movements and the perception of time

2.10 Perceived Body Movements and the Perception of Time

As has been discussed, both English and Mandarin have two types of temporal models: the Moving Ego model and the Moving Time model. Studies (e.g., Boroditsky, 2000; Hartmann & Mast, 2012) have found that people who experienced body movements were more likely to activate the Moving Ego model. Boroditsky and Ramscar (2002) conducted a series of experiments that tested the effect of the availability of temporal representation on people's temporal judgment. They asked people an ambiguous question about a meeting and compared results between people who experienced body movements and people who had been waiting. The results revealed that while answering a question such as: "Next Wednesday's meeting has been moved forward two days. What day is the meeting now that it has been rescheduled?", people who experienced body movements were more likely to think that the meeting would be on Friday since they had experienced self-moving, and people who had been waiting were more likely to think that the meeting would be on Monday because they had experienced time-moving. Borodit-

sky and Ramscar's finding suggested a close connection between temporal judgment and bodily experience: the two types of temporal models might be based on concrete experiences of moving through space. However, given the fact that the two types of temporal models have different status in the two languages, it will lead us to my third research question.

2.11 The Third Research Question

If English and Mandarin speakers show different body sway patterns, which means that the processing of temporal information, including perception and production, could influence people's bodily motor responses according to the temporal direction in each language, the current study then needs to test how general the effect is. The third research question is:

3. How general is the effect of temporal perception on body movements?

In order to answer such a question, I will answer the following more specific questions.

- (a) Do English speakers walk faster when listening to information about the future than when listening to information about the past?
- (b) Do Mandarin-English bilinguals walk faster when listening to information about the future than when listening to information about the past in English?
- (c) Do ME bilinguals walk faster when listening to information about the past than when listening to information about the future in Mandarin?

In order to answer these questions, the third experiment is designed and will be presented in Chapter 5. Mandarin monolinguals were not tested for practical reasons.

We can see that the current study first needs to test the differences between Mandarin and English speakers on how they might associate time with directions differently on the three dimensions (sagittal, vertical and transverse). If there are any differences between speakers of the two languages, especially on the sagittal dimension, it will then test the effect of the sagittal

direction of time on body sway. After that, if people sway their bodies according to the spatio-temporal metaphoric language in each language, which means that language has an effects on body movement patterns, the study will then test the effect of temporal information on people's walking speeds and see whether speakers of the two languages could still behave according to the languages. However, there is one more issue I have not yet addressed, which can be tested within each of the three experiments, namely the effect of spatial cues embedded in temporal expressions.

2.12 The Effect of Spatio-Temporal Metaphoric Language on Perception of Time

The previous sections looked at the importance of using gestures to study cognitive processes as well as conceptual imagery and provide information about people's mental time lines and both elicited and spontaneous gestures can reveal conceptual mappings. Behaviourally implicit tasks such as body sway (Miles, Nind, & Macrae, 2010) can also reveal implicit associations between time and direction in mental representations. In this section I will talk about one factor that has not yet been tested in implicit tasks, namely whether overt spatial information embedded in temporal expressions can have an immediate effect on people's motor responses.

As discussed, several factors can affect how people associate time with space: the bodily experience of moving (Boroditsky & Ramscar, 2002), cultural artifacts like writing and reading directions (Fuhrman & Boroditsky, 2010), and temporal sequences (Boroditsky, 2000). Spatio-temporal metaphoric language contains spatial information. For instance, in English the phrase *the day before yesterday* contains a spatial word *before* that indicates a sequential order, and in Mandarin, the phrase *shang-ge yue* (last month) contains a spatial word *shang* that means up. The effect of overtly embedded spatial information in spatio-temporal metaphoric language has rarely been tested. One reason for this is that the whole idea of spatio-temporal metaphors is based on the use of spatial language in temporal expression, therefore analysing spatial language could easily lead to a circular argument. However, overt spatial information can still be used in experimen-

tal stimuli. For instance, Gu et al. (2013, 2014) found that when processing Mandarin spatio-temporal metaphoric language on the vertical dimension such as up and down, bilinguals of Mandarin and English are more likely to produce vertical gestures in Mandarin than when processing the corresponding translation in English. Lai and Boroditsky (2013) found that the use of spatial language in temporal expressions had an immediate effect on how Mandarin speakers associate time with space, although they only used an explicit task rather than using an implicit task, which leads us to the current study. More importantly, Chui (2011) observed a conversation between Mandarin speakers, and found that the subject pointed back when he talked about things that happened *yesterday*; however, when he was saying *zhiqian* (literal meaning that before), which means previously, he pointed front.

As we can see, such an observation is consistent with the immediate effect of overt spatial information on Mandarin speakers' mental representation of temporal sequences. It also suggests that there might be two forces affecting their temporal direction on the sagittal dimension. On the one hand, when there is no spatial information, the overall associations that Mandarin speakers have between space and time could be front-future and back-past. On the other hand, lexical items in temporal expressions can trigger different associations.

The current study on the effect of overt spatial information is inspired by Chui's study (2011) and will use conventional temporal phrases as stimulus materials. Conventional temporal phrases are temporal phrases that are used by people on a daily basis such as *tomorrow*, *yesterday*, *two days ago*, *last year* and etc. Some of them are spatio-temporal metaphoric language whereas some are not. I will focus on the effect of linguistic encoding of overt sagittal spatial cues on motor responses. There are two reasons for choosing sagittal spatial cues. Firstly, overt vertical cues have been found to make people who speak Mandarin think about time vertically, which is less likely when they process the corresponding English temporal information. However, sagittal spatial information has not yet been tested. Secondly, studies testing overt spatial cues have so far only tested bilingual speakers of Mandarin and English, but never compared bilinguals with Mandarin monolinguals. Testing bilinguals in different language contexts might reveal effect

of languages; however, it is also necessary to compare bilinguals with monolinguals and see how the effect of languages makes the former different from the latter. Therefore, the current study will do so.

2.13 The Last Research Question

Overt spatial information in spatio-temporal metaphoric language can affect how people produce gestures. For example, Mandarin speakers are more likely to produce a vertical gesture when an expression contains up or down (Gu et al., 2013, 2014). Mandarin speakers also could point forward for the past when the word contains *qian* (front), and they will point back for the past when a temporal word does not contain any spatial information, despite the fact that such a result was only observed from a single case study (Chui, 2011). Therefore, overtly embedded sagittal spatial words have not yet been systematically tested in implicit tasks. Existing studies only show that they might have an immediate effect on people's perception of time. The current study will test them in an implicit task (body sway). Drawing on evidence from existing studies on how Mandarin speakers are affected by overt spatial information, the current study poses the following research question:

4. Could spatial cues in temporal expressions affect how Mandarin speakers perceive time?

In order to answer this question, I will address the following more specific questions:

- (a) Do Mandarin speakers associate different directions with temporal information that lacks spatial cues than when the temporal information contains the spatial cue front (or back)?
- (b) If yes, can the presence of spatial cues in temporal expressions affect Mandarin speakers' body movement patterns (in both body-sway and walking)?

In order to answer this questions, two types of experimental materials are designed: temporal expressions with spatio-temporal metaphoric language

and those without it. They will be tested in the three experiments mentioned in order to see how they might affect the participants.

To provide an overview of the whole thesis project, I have restated all research questions, along with various sub-questions.

1. How do English and Mandarin speakers and bilinguals of the two languages associate time with direction on each dimension?
 - (a) Do native English speakers and native Mandarin speakers have different mental timelines on the sagittal and the vertical dimensions? In other words, will English speakers associate front and up with the future and back and down with the past, and will Mandarin speakers associate back and down with the future and front and up with the past?
 - (b) If there are differences, will bilinguals associate front with the future and back with the past when speaking English or perceiving temporal information in English?
2. If English and Mandarin have different temporal directions on the sagittal dimension, do monolinguals and bilinguals of the two languages have different body sway patterns during the processing of temporal information about the past and the future?
 - (a) Do native English speakers sway their bodies according to the temporal direction in English during the perception and the production of temporal information in English?
 - (b) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in Mandarin during the perception and the production of temporal information in Mandarin?
 - (c) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in English or in Mandarin during the perception and the production of temporal information in English?
3. How general is the effect of temporal perception on body movements?

- (a) Do English speakers walk faster when listening to information about the future than when listening to information about the past?
 - (b) Do Mandarin-English bilinguals walk faster when listening to information about the future than when listening to information about the past in English?
 - (c) Do ME bilinguals walk faster when listening to information about the past than when listening to information about the future in Mandarin?
4. Could spatial cues in temporal expressions affect how Mandarin speakers perceive time?
- (a) Do Mandarin speakers associate different directions with temporal information that lacks spatial cues than when the temporal information contains the spatial cue front (or back)?
 - (b) If yes, can the presence of spatial cues in temporal expressions affect Mandarin speakers' body movement patterns (in both body-sway and walking)?

Studies on perception of time between English and Mandarin have been conducted in many different countries and regions such as the UK, the U.S., Taiwan, Hong Kong, Mainland China, and Singapore. For the current study, I designed and conducted three experiments. Each experiment addresses one of the first three research questions, and the fourth research question will be answered by collecting results from all three experiments. The first experiment tests how time (with and without overt spatial cues) is associated with direction in English and Mandarin. By doing so, the first experiment can show cross-cultural differences, effects of language context, and immediate effects of spatio-temporal metaphors on the perception of time. The second experiment tests the effect of the perception and production of temporal information (with and without overt spatial information in temporal expression) on body-sway and therefore the second experiment can answer the second research question. The second experiment can help us understand how language and time can affect people's body movement patterns

and how sagittal spatial information affects people's body movement directions. Findings from the third experiment will show us how general the effect of the temporal perception on body movements is. In the next chapter, I will present the first experiment that tested how Mandarin and English monolingual and bilingual speakers associate time with directions on each physical dimension.

Chapter III

Explicit Associations between Time and Space in English and Mandarin

In the current study I have selected English and Mandarin because the two languages appear to exhibit different temporal directions on both the sagittal and the vertical dimensions, which make them ideal for testing for variation in body movement patterns. As I have discussed in the last chapter, studies on the perception of time have paid much attention to how different languages use different spatial properties to describe time. However, less attention has been paid to within-dimensional differences between languages. For English and Mandarin, the difference between the two groups of speakers with regard to their perception of time has been found to support linguistic relativity; that is, the different structures between languages will lead speakers of the languages to have non-linguistic cognitive differences. However, findings on this matter are controversial and are still under debate based on inconsistent results (e.g., Boroditsky, 2001, 2008; Chen, 2007; January & Kako, 2007; Tse & Altarriba, 2008). For example, Boroditsky (2001) found that Mandarin speakers are affected by vertical primes compared with English speakers, suggesting that the former group conceives time vertically. However, Chen (2007), January and Kako (2007), and Tse and Altarriba (2008) failed to replicate results from the original study. Two studies that have been conducted recently (Boroditsky et al., 2011; Miles et al., 2011) used a similar methodology and found that Mandarin speakers were affected when a keyboard was vertically or horizontally located when being asked to press buttons as responses to visual stimuli that revealed temporal sequences; however, English speakers were only affected when the keyboard was horizontally located. The latter two studies show that unlike Mandarin speakers, English

speakers do not have a preferred vertical temporal direction.

As has been pointed out by Chen and O'Seaghdha (2013), factors that affect people's mental representation of time are very complex, and the perception of time cannot be explained by just one or a few factors. It has also been shown that recent exposure to spatio-temporal metaphors from a language can influence people's mental representation of time, and that these effects can persist long-term (Lai & Boroditsky, 2013). However, recent exposure to spatio-temporal metaphors, with specific regard to overt spatial information, was only found from explicit tasks. Although studies on gesture (e.g., Gu et al., 2013) found that overt spatial information on the vertical dimension in Mandarin can make bilinguals of Mandarin and English produce more vertical gestures, which can be seen as strong evidence for metaphoric thinking since gesture can reveal cognitive processes, the immediate effect of spatial information on the sagittal dimension in Mandarin has not been tested in implicit tasks. Apart from language, the cultural focus in a given society can show different patterns from what spatio-temporal metaphors (linguistic data) explain (de la Fuente et al., 2014). People who speak the same language could have different perceptions of time if they are in different age groups (de la Fuente et al., 2014), or geographically they live in different countries (Chen, Friedrich, & Shu, 2015; Chen & O'Seaghdha, 2013). Studies of the mental representation of time in Mandarin speakers have been carried out on both bilinguals and monolinguals from different locations, such as the U.S., Taiwan, Singapore and Mainland China, where results found that:

1. There are cross-linguistic effects on the perception of time for ME bilinguals. For example, recognizing that the Moving Time model is the dominant temporal model in Mandarin, Lai and Boroditsky (2013) found that, ME bilinguals are more likely to use the Moving Time in English than English monolinguals; however, they are also less likely to use the Moving Time model in Mandarin than Mandarin monolinguals. Fuhrman et al. (2011) also found that ME bilinguals with high Mandarin proficiency were more likely to arrange time vertically than ME bilinguals with low Mandarin proficiency. Both studies suggest that the knowledge of one language can affect how people use temporal

metaphors in the other language.

2. Language has immediate effects on people's perception of time. For example, Lai and Boroditsky (2013) found that when asking ME bilinguals to point directions in the Mandarin context, they were more likely to use the sagittal dimension to think about time after being prompted with front-back spatio-temporal metaphors, and they were also more likely to use the vertical dimension to think about time after being prompted with up-down spatio-temporal metaphors.
3. Overtly embedded spatial information on the vertical dimension can make ME bilinguals produce vertical gestures (Gu et al., 2013, 2014), which can be seen as implicit associations between time and vertical directions. However, how Mandarin speakers respond to sagittal information has not been studied in implicit tasks.
4. The perception of time may be informed by the direction that characters are organized in written forms of these language. For Mandarin, the likelihood of arranging time from top to bottom is dependent on the amount of exposure to vertical writing/reading experience (Bergen & Lau, 2012; de Sousa, 2012; Fuhrman et al., 2011). For example, for people from Taiwan, speakers who are more proficient in Mandarin are less likely to arrange time from left to right, which is consistent with fact that traditional Chinese uses both leftward and downward writing directions.
5. ME bilinguals can have different mental timelines: the transverse, the sagittal and the vertical. Different mental timelines can be activated by both languages and cultural figures, such as Jet Li and Brad Pitt (Miles et al., 2011), suggesting that sociolinguistic context can affect how bilinguals see the world.

The current study tests Mandarin bilinguals and English monolinguals in New Zealand. Studies (Fuhrman et al., 2011; Lai & Boroditsky, 2013) have tested bilinguals of the two languages with varying levels of proficiency in each language, and found a close connection between language proficiency and how likely it is that bilinguals would choose a certain type of temporal

model. For example, Lai and Boroditsky (2013) found that the ME bilinguals who were more proficient in Mandarin were less likely to use the Moving Ego model, whereas the bilinguals who were more proficient in English were more likely to use the Moving Ego model. These studies have been conducted on speakers from different regions such as Mainland China, Taiwan and the U.S. There are no documented studies in the literature on New Zealand Mandarin-English bilinguals and native New Zealand English speakers. However, given the near-consistent results from ME bilinguals across different regions, it is believed that bilinguals living in New Zealand would behave as their counterparts in other countries. The current study will recruit late ME bilinguals whose first language (L1) is Mandarin and the second language (L2) was acquired after childhood. One reason for testing late bilinguals is that if language can affect how people understand the world, then the experience of a second language (even after childhood) would still be expected to have such an effect. The other reason is that it has been found that ME bilinguals with higher proficiency in Mandarin are more likely to associate the future with back, and therefore, recruiting late bilinguals could maximize the chance of getting a cross-linguistic effect.

Table 3.1 is a list of literature that recently tested how English and Mandarin monolinguals and bilinguals associated time with direction on the three dimensions. On the one hand, existing studies mostly compare the two languages as horizontal (sagittal or transverse) versus vertical dimensions (e.g., Boroditsky, 2001, 2008); in other words, how likely Mandarin/English speakers are to use certain dimensional representations of time. On the other hand, some studies also tested how speakers of the two languages associated time with directions on different dimension. As we can see in studies from Boroditsky (2001, 2008) and Fuhrman et al. (2011), Mandarin speakers are more likely to think about time vertically; this has been shown in both implicit and explicit tasks. However, few studies have tested bilingual speakers and compared the two languages within each dimension, though Fuhrman et al. (2011) revealed comparisons on three different dimensions: transverse (left-right), vertical (up-down) and sagittal (front-back).

Table 3.1: Recent studies testing how time and space are associated in Mandarin and English on the three different dimensions.

study	language group	language tested	dimension tested	task	task type	result
Boroditsky (2001)	native English and Mandarin speakers	English	vertical and transverse	RTs for sentences judgment (computer screen)	implicit association	Mandarin speakers think about time vertically when being tested in English.
	ME bilinguals	English	vertical and transverse	RTs for sentences judgment (computer screen)		Bilinguals who started learning English later in life were more likely to think about time vertically in English.
	native English speakers	English	vertical	training (computer screen)		English speakers who were trained to think about time vertically behaved like Mandarin speakers.
Boroditsky (2008)	native English speakers	English	any	pointing (3D space)	explicit decision	English speakers were less likely to use the vertical dimension to point time than Mandarin speakers. No differences were found between ME bilinguals in different language contexts.
	native Mandarin speakers	Mandarin				

	native Mandarin speakers	English				
Fuhrman et al.(2011)	native English and Mandarin speakers	no language involved (but within language contexts)	three dimensions	RTs for compatibility task (computer screen)	implicit association	Left-past and right-future for both groups, up-past and down-future for Mandarin speakers. No preferences were found on the sagittal axis.
	native English and ME bilinguals	English		pointing (3D space)	explicit decision	Mandarin speakers with more vertical reading experience were less likely to arrange time rightward. Bilinguals who were more proficient in Mandarin were more likely to arrange time downward, and backward (with the past in front).
	ME bilinguals in the U.S	Mandarin				
	ME bilinguals in Taiwan	Mandairn				

Lai & Boroditsky (2013)	ME bilinguals and monolinguals	native language for monolinguals, two languages for bilinguals	sagittal	ambiguous question	explicit decision	Bilinguals in English were more likely to use the Moving-time metaphor than English monolinguals. Bilinguals in Mandarin were less likely to use the Moving-Time metaphor than Mandarin monolinguals.
	ME bilinguals	Mandarin	any	pointing (3D space)		Bilinguals were more likely to adopt vertical time when prompted with up-down metaphor, and they were more likely to adopt sagittal time when prompted with front-back metaphor.
Gu et al. (2013; 2014)	ME bilinguals	in both language	vertical and sagittal	co-speech gesture	implicit association	When speaking Mandarin, bilinguals are more likely to produce vertical gestures for temporal expressions that contain vertical spatial information.

Chen & O'Seaghdha (2013)	native English speakers, native Mandarin speakers from Taiwan and China	no language involved	vertical and transverse	RTs for compatibility task (computer screen)	implicit association	Only horizontal effects for English speakers and Mandarin speakers from China. Only vertical effects for Mandarin speakers from Taiwan.
Walker et al. (2014)	native English speakers	English	vertical and transverse	RTs for compatibility task (auditory stimuli)	implicit association	earlier-front, later-back compatibility effects.
Sell & Kaschak (2011)	native English speakers	English	sagittal	RTs for compatibility task (computer screen) that involves arm movements	implicit association	past-back, future-front compatibility effects
Miles et al. (2010b)	native English speakers	English	sagittal	measuring body-sway	implicit association	past-back, future-front compatibility effects
Miles et al. (2011)	ME bilinguals	no language involved	sagittal and transverse	arranging cards that represent temporal sequence	explicit task	Bilinguals arrange cards from left to right for Brad Pitt, but from top to bottom from Jet Li

Casasanto & Jasmin (2012)	native English speakers	English	sagittal and transverse	co-speech gesture	implicit association	Front-future, back-past when asked to gesture deliberately; right-future left-past when producing spontaneous gestures
Boroditsky et al. (2011)	native English, Mandarin speakers	no language involved	horizontal and vertical	judging sequence	implicit association	Mandarin speakers were affected by vertically located keyboard; English speakers were affected horizontally

When using the sagittal dimension to think about time, the picture is less clear for Mandarin than for English. For example, by testing ME bilinguals in a compatibility (implicit) task, Fuhrman et al. (2011) found that Mandarin speakers have no preferred temporal direction on the sagittal dimension. However, when testing bilinguals in a pointing task (explicit), they found that Mandarin speakers with higher Mandarin proficiency associated front with the past and back with the future. The latter result is also consistent with the result from Lai and Boroditsky (2013). For English, for the Moving Ego model, many studies have found a compatibility effect on future-front and past-back mappings (e.g., Casasanto & Jasmin, 2012; Miles, Nind, & Macrae, 2010; Sell & Kaschak, 2011).

When using the vertical dimension to think about time, Mandarin speakers associate up with the past and down with the future, which has been tested in implicit (Boroditsky, 2001; Fuhrman et al., 2011; Gu et al., 2013, 2014) and explicit tasks (Boroditsky, 2008; Fuhrman et al., 2011; Lai & Boroditsky, 2013). For English, though conceptual metaphor theory argues up is associated with the future and down is associated with the past (Radden, 2004), studies have not found such a result (Fuhrman et al., 2011). Some studies (e.g., Boroditsky, 2001) also found that English can learn the downward time after training.

When using the transverse dimension to think about time, Mandarin speakers' associations between time and direction are affected by their experience of leftward reading (Chen & O'Seaghdha, 2013). For English, clear associations between left and the past, and between right and the future, have been found from implicit tasks described by Fuhrman et al. (2011) and Walker, Bergen, and Núñez (2014), and a gesture study conducted by Casasanto and Jasmin (2012).

Existing studies that conducted behavioral experiments found little evidence for the preferred directions on the sagittal dimension for Mandarin and on the vertical dimension for English from implicit tasks. Temporal directions for Mandarin on the sagittal dimension are only based on linguistic data, and it does not mean that Mandarin speakers' mental representations of time would be consistent with spoken metaphor (Yu, 2012). For example, de la Fuente et al. (2014) and Casasanto (2016) found dissociation be-

tween temporal language and temporal thinking, suggesting that how time is described in spoken metaphor might not reflect speakers' mental representations of time. Based on the possible difference between linguistic data (spoken metaphor) and people's mental representations of time, one might ask how Mandarin speakers would respond if they are required to think about time on the sagittal dimension.

Although CMT predicts that time can be both upward and downward in English, existing studies found that English speakers showed no preferential vertical temporal directions. As discussed, this is probably due to at least two reasons. First, in English, the future-down metaphor is not coupled with a past-up metaphor. Second, the word *up* itself sometimes does not mean spatially being upward, such as in *turn up*, and therefore the word *up* probably may not have a temporal meaning if we assume that temporal representations derive from spatial frameworks. The current study tests how English speakers would respond if they were required to think about time vertically. It also tests whether Mandarin and English speakers would respond differently within each dimension. If there are any differences within a single dimension between the two languages, could language affect bilinguals' perception of time?

Furthermore, in the existing literature, studies tried to avoid using lexically embedded temporal metaphors (spatio-temporal metaphors) when testing the participants' mental representation of time, and only a few studies used this kind of experimental stimuli. For example, Lai and Boroditsky (2013) used spatio-temporal metaphors as experimental material, and tested them on ME bilinguals in Mandarin. Overt vertical information has been tested in gesture studies, such as Gu et al. (2013, 2014), who tested the effect of overt vertical temporal expression on co-speech gestures. Overt sagittal spatial information in Mandarin has not yet been tested in implicit tasks, which is the focus of the current study.

Another important issue to address is that very few studies have compared ME bilinguals' behaviours with those of monolinguals. In the current study, not only should bilinguals be tested in different language conditions, but monolinguals of the two languages are also needed as control groups. If there are any effects of language on perceptions of time, bilinguals might

behave differently from monolinguals. Therefore, in the current study we are going to see whether Mandarin-English bilinguals as well as monolinguals of Mandarin think about temporal words differently in a three-dimensional task.

Therefore, the first experiment is designed to answer the first research question and part of the last research question that were asked at the end of Chapter 2.

1. How do English and Mandarin speakers and bilinguals of the two languages associate time with direction on each dimension?
 - (a) Do native English speakers and native Mandarin speakers have different mental timelines on the sagittal and the vertical dimensions? In other words, will English speakers associate front and up with the future and back and down with the past, and will Mandarin speakers associate back and down with the future and front and up with the past?
 - (b) If there are differences, will bilinguals associate front with the future and back with the past when speaking English or perceiving temporal information in English?
4. Could spatial cues in temporal expression affect how Mandarin speakers perceive time?
 - (a) Do Mandarin speakers associate different directions with temporal information that lacks spatial cues than when the temporal information contains the spatial cue front (or back)?

The first experiment aims at revealing within-dimensional differences by testing monolingual and bilingual speakers of the two languages. The effect of Mandarin overt spatial information will also be tested in order to see whether they can have an impact. This work takes Fuhrman and Boroditsky's (2010) pointing paradigm as inspiration, which asks participants to point freely to temporal words by using the 3D space around them, and extends into a longer task with several improvements.

3.1 Hypotheses

In the current study, overt spatial information will be addressed as **directional cues** or **spatial cues**. FUTURE and PAST will be addressed as **time type**. Referring to the aims of the current experiment, I hypothesize the following potential results based on the past research.

When participants can point direction freely:

- (a) Native English speakers will use the transverse and sagittal dimensions to think about time more often than using the vertical one, which is based on prior experimental evidence from Boroditsky (2001). When they choose to use the sagittal and transverse dimensions, they point front for the future more often than for the past, and they point right for the future more often than for the past; these choices are based on prior experimental evidence from Miles, Nind, and Macrae (2010) and Walker et al. (2014). When speakers choose to use the vertical dimension, they do not have preferred temporal directions (Boroditsky et al., 2011; Miles et al., 2011).
- (b) ME bilinguals in the English context will behave in a similar way as English speakers.
- (c) ME bilinguals in the Mandarin context will use the vertical dimension more often than using it in the English context, which is based on evidence from Boroditsky (2001) and Fuhrman et al. (2011). However, they will use the sagittal dimension more often than using the vertical one, which is based on evidence from Chen (2007) and Boroditsky (2008). When bilingual speakers choose to use the sagittal dimension, they point front for the future more often than for the past when there are no sagittal cues, and they point back for the future more often than for the past when there are sagittal cues. These hypotheses are based on prior experimental evidence from Chui (2011) and Lai and Boroditsky (2013). When bilingual speakers choose to use the vertical dimension, they point up for the past more often than for the future, which is based on prior experimental evidence from Fuhrman et al.

(2011), Lai and Boroditsky (2013) and Gu et al. (2014). Bilinguals point left for the past more often than for the future.

- (d) Mandarin monolinguals will behave in a similar way as ME bilinguals in the Mandarin condition. However, the effect of sagittal cues will be stronger for them than for bilinguals.

When participants are forced to only point front and back:

- (e) Native English speakers point front for the future more often than for the past, which is based on evidence from Miles, Nind, and Macrae (2010).
- (f) ME bilinguals in the English context will show similar behaviours to English speakers.
- (g) ME bilinguals in the Mandarin context point front for the future more often than for the past when there are no sagittal cues, and they point back for the future more often than for the past when there are sagittal cues. These are based on experimental evidence from Lai and Boroditsky (2013) and observation (Chui, 2011).
- (h) Mandarin monolinguals will show similar behaviours to ME bilinguals in the Mandarin condition. The effect of sagittal cues will be stronger for them than for bilinguals.

When participants are forced to point only up and down:

- (i) English monolinguals do not have preferred temporal directions.
- (j) ME bilinguals in the English condition will show similar behaviours to native English speakers.
- (k) ME bilinguals in the Mandarin condition point up for the past more often than for the future regardless of vertical cues. These hypotheses are based on prior experimental evidence from Fuhrman et al. (2011) and Lai and Boroditsky (2013).
- (l) Mandarin monolinguals will show similar behaviours to bilinguals in the Mandarin condition.

When participants are forced to point only left and right:

- (m) All participants will associate left with the past and right with the future.

Hypotheses for the associations between time and direction for each language group/condition are summarized in Table 3.2. Monolinguals and bilinguals in the same language context are only described in terms of language condition because the hypotheses predict that monolinguals and bilinguals in the same language context will behave in similar ways. The grey colour under the column ‘Dimension’ indicates participants' primary dimension when they can point freely, whereas the n/a means there are no spatial cues in the corresponding dimension.

Table 3.2: Hypotheses on the association between time and direction on the three dimensions from the two language conditions. n/a – non applicable.

Group	Dimension	Result	
English condition (monolinguals and bilinguals)	sagittal	Front for the future more often than for the past	
	vertical	No preferred direction on the vertical axis	
	transverse	Right for the future more often than for the past	
Mandarin condition (monolinguals and bilinguals)		Having cues	No cues
	sagittal	Back for the future more often than for the past	Front for the future more often than for the past
	vertical	Up for the past more often than for the future	Up for the past more often than for the future
	transverse	n/a	Right for the future more often than for the past

As has been mentioned, this experiment employs a pointing paradigm; in a pointing task participants are directed to indicate a direction of their choos-

ing using their hands (e.g., pointing up, down, front, back, etc.). The three-dimensional pointing task was used when studying temporal perception between English and Hebrew speakers (Fuhrman & Boroditsky, 2010). The advantage of finger pointing is that it is practical and easy to set up in an experiment. Moreover, finger pointing avoids some disadvantages associated with the use of computer devices. The problem with using computer devices such as keyboards or mounted joysticks is that such methods require participants to transfer between dimensions. For example, when testing people on the vertical dimension by using a keyboard (which is horizontally located on a desk), participants need to constantly mentally transfer between the vertical and sagittal dimensions.

Furthermore, button pressing can only test two dimensions at the same time (e.g., either the transverse and vertical dimensions, or the transverse and sagittal dimensions). Similarly, traditional devices such as keyboards or joysticks cannot test the vertical and sagittal dimensions at the same time. Several existing studies used keyboards to test participants on the sagittal dimension, but this led to another problem: no matter which device was used, the device was always in front of the participants. Therefore, the two directions revealed by the device (i.e. front and back) were in fact not about front and back, but were both in front of people with one option relatively further away than the other. In other words, by using a computer device such as pressing buttons in front of them, participants need to shift the centre of the 3D space from their bodies to the keyboard in front of them (Fuhrman et al., 2011), but a three-dimensional pointing paradigm avoids this problem. Another advantage of finger pointing is that it is a deictic and metaphoric gesture that is frequently produced and is able to reflect conceptual mapping between time and space. Thus, finger pointing is natural to people; it does not require any special training, and reduces demands on participants that could potentially confuse or distract them from the experimental task.

3.2 Methodology

Participants

Ten native New Zealand English monolingual speakers, 10 Mandarin-English bilingual speakers and 10 Mandarin monolingual speakers were recruited. The English speakers and the bilinguals were undergraduate students at the University of Canterbury, whose ages ranged from 18 to 34 years and all were recruited by using public signs posted around the campus. All the bilinguals reported that they were originally from mainland China. There were seven male and three female bilinguals, as well as seven female and three male English monolinguals. The participants were offered shopping vouchers in exchange for their time. One female and nine male Mandarin monolinguals were recruited from a vehicle research academy located in Chang Chun city, China. Their ages ranged from 30 to 40 years. Educational level was unknown, however, based on the nature of their jobs, their education levels were presumably high school and technological college.

A questionnaire was used before the experiment. The questionnaire asked whether they could speak languages other than English, and the proportion of the use of the languages on daily basis by using six agree/disagree questions for each language (See appendix). Self-reporting has been used in the existing studies but in different ways. Fuhrman et al. (2011) adopted a self-reporting that involved evaluation of English proficiency and each participant had to give a number out of five. The current criteria were that their answers to at least four questions indicated that their Mandarin was stronger than their English and they had no knowledge of Cantonese or Teochew. Such criteria were used for recruiting late bilinguals. All the participants filled out the questionnaire before the experiment in order to further ensure that they fit the criteria.

Ten bilinguals applied to take part in the study and all of them fit the criteria so no one was excluded according to these criteria. All the bilinguals reported that they started to learn Mandarin before the age of 7 years, spent more time speaking Mandarin than English, and mainly spoke Mandarin at home and with friends. Some of the English speakers did not speak other languages at all, and some of them reported that they had a little knowledge

of other languages, but it was very limited. One English speaker was excluded at the recruitment stage because he reported that he could speak Māori. The reason for excluding him was that in Māori the past is seen as ahead, which might affect his perception of time. For the Mandarin monolingual speakers, all of them reported that they had little knowledge of English, and never used English. In the rest of the chapter the three groups will be addressed as the English monolinguals, the bilinguals and the Mandarin monolinguals.

The participants were informed that the experiment was to study how people associate directions with concepts before participation. After that, they signed a consent form (See appendix), so they had a chance to agree or disagree with the use of the recorded data.

Materials

The material was a list of eighty words in both languages. For the material in each language, there were twelve pairs of time-related words, some of which included overt spatial cues. For the twelve pairs of time-related words in Mandarin, ten words contained sagittal spatial cues and six words contained vertical cues. For their counterparts in English, four happened to contain sagittal spatial cues because English words were direct translations from Mandarin, and there were no vertical cues in English. The rest of the list comprised fillers of five pairs of words related to time of day, five pairs related to health, five pairs related to emotion, five pairs of random words with positive and negative values and sixteen non-paired random words. In each pair related to time of day, one was related to daytime and one was related to night. In each pair related to health and emotion, one had a positive meaning and the other one a negative meaning. The reason for including negative and positive meanings in each pair was to include stimuli that were likely to elicit confident answers. Since Mandarin monolinguals were tested in Mainland China, non-paired random words tested for them contained different words from the ones that were used for the other groups. For example, the word *Beijing* was tested for Mandarin monolinguals, whereas *Auckland* was tested for English monolinguals and bilinguals in the two conditions.

Mandarin time-related words consisted of temporal words that contained

overt spatial information and those that had no such information. There were two types of overt directional information, which will be addressed as directional cues or spatial cues. English time-related words were direct translations from their Mandarin counterparts. There were four words in English containing *before* and *after*, however, their existence was only a side-effect of translational equivalence. They will be discussed when presenting model fitting strategies. The two types of cues in Mandarin are as follows.

1. The first type consisted of cues in both English and Mandarin Chinese on the sagittal dimension. In this type of cue, *qian* and *hou* are used for describing temporal sequences or deictic direction (there are disagreements among studies, but based on recent studies (Yu, 2012), they are highly likely to be consistent with the Moving Time metaphor). The Mandarin word *qian* means ‘before’ or ‘front’ in English, and it can be used in both spatial and temporal situations. The Mandarin word *hou* means ‘after’ or ‘back’ in English, and it also can be used as a spatial and a temporal reference. For example, a word *qian tian* (literal meaning would be front day) means the day before yesterday, and *liang-ge-yue hou* (literal meaning would be two months back) means two months later or in two months' time depending on the context.
2. The second type consisted of cues on the vertical dimension. In this type of cue in Mandarin, *shang* and *xia* were used for describing temporal information. The Mandarin word *shang* and *xia* means up or upper and low or lower in English respectively. For example, *shang ge yue* (literally means upper month) means last month and *xia ge yue* (literally means lower month) means next month.

Table 3.3 gives the numbers of each type of spatial cues for the past and the future in the two languages.

Table 3.3: The numbers of each type of spatial cues for each time type in the two languages.

Language	Mandarin		English	
Time Type	Past	Future	Past	Future
Type 1: Sagittal cues	5	5	2	2
Type 2: Vertical cues	3	3	0	0
No cues	4	4	10	10

In order to make it easier for future reference, the Mandarin cues *qian*, *hou*, *shang*, and *xia* (literally meaning front, back, up and down respectively) will be addressed as Mandarin-past-front cue, Mandarin-future-back cue, Mandarin-past-up cue and Mandarin-future-down cue respectively. The English *before* and *after* cues will be discussed in the section of model fitting strategies.

For temporal words that did not have any overt spatial information in the two languages, they were words such as *past*, *future*, *the year 1990*, *the year 2020* and etc. Time-related words are shown in Table 3.4:

Table 3.4: List of time-related words in both languages and type of cues, spatial cues in Mandarin are in **BOLD**.

Word in English	Cues	Time Type	Word in Mandarin	Cues
future	no cue	future	jiang lai	no cue
next year	no cue	future	ming nian	no cue
the year 2020	no cue	future	2020 nian	no cue
tomorrow	no cue	future	ming tian	no cue
last year	no cue	past	qu nian	no cue
past	no cue	past	guo qu	no cue
the year 1990	no cue	past	1990 nian	no cue
yesterday	no cue	past	zuo tian	no cue
in four years' time	no cue	future	si nian hou	type 1
in three days' time	no cue	future	san tian hou	type 1
your descendants	no cue	future	ni de hou dai	type 1
the day after tomorrow	type 1	future	hou tian	type 1
the year after next	type 1	future	hou nian	type 1
four years ago	no cue	past	si nian qian	type 1
three days ago	no cue	past	san tian qian	type 1
your ancestors	no cue	past	ni de zu xian	type 1
the day before yesterday	type 1	past	qian tian	type 1
the year before last	type 1	past	qian nian	type 1
next month	no cue	future	xia ge yue	type 2
next Saturday	no cue	future	xia zhou liu	type 2
next week	no cue	future	xia zhou	type 2
last month	no cue	past	shang ge yue	type 2
last Saturday	no cue	past	shang zhou liu	type 2
last week	no cue	past	shang zhou	type 2

Procedure

Native English and Mandarin speakers did one session in their native languages, and bilingual speakers did two sessions in two different languages. Half of the bilinguals did the English part first to counterbalance. The two sessions for each bilingual were at least one week apart. Each of the eighty words appeared once in each condition. Words were also randomized in each

condition and there were four conditions.

The first condition was always an ‘any-direction’ condition, in which the participants could point in any direction they wanted to when they saw the words. In the other three conditions, the participants' pointing directions were restricted. The other three conditions were ‘front-back only’ (sagittal-only), ‘left-right only’ (transverse-only) and ‘up-down’ only (vertical only). The three restricted conditions were in random orders. At the beginning of each of the three restricted conditions, instructions appeared on the screen which told the participants that they can only point two opposed directions on one dimension, and in each of the three conditions the participants only pointed two directions. The whole experiment was designed and run in E-prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA, USA) and started by showing three pages of instructions, which told the participants to press the SPACE key to see the next word, and they must always use the same hand to press as they have used to point. This was to minimize the tendency that people might repeat their previous action. There were three minutes between conditions so they could rest their hands for a while. It took each participant about forty minutes to complete the task. The experiment for each participant was video-recorded, which was approved by the Human Ethics Committee of the University of Canterbury. The use of the recorded video was to collect people's responses. All of the responses were coded manually and double-checked by the experimenter and checked by an independent research assistant who was blind to the experimental hypotheses before any further analyses.

Data Coding

Results were analyzed by using R (R Development Core Team, 2015). In the any-direction condition, since the current study only focuses on time-related words, people's responses to them were analyzed separately. The participants' responses to time words in each restricted condition were also analyzed. The participants' responses were coded by working through the videos and their pointing motion was coded as one of the six directions ‘up’, ‘down’, ‘front’, ‘back’, ‘left’ and ‘right’. The videos captured both the screen

and the participants' hand motion, therefore during the coding process one can see what stimulus the participants were responding to. Since there were 10 trials at the beginning prompting the participants to point only the six directions, it was found that for the testing targets, which were temporal expressions, the participants' pointing motions were always clearly in one direction. Some participants did not point clearly in one direction when they were asked to point directions for places such as *the mountain* or *the river*, however these fillers were not the focus in the current study and they were not analyzed. The categorization was done by the experimenter and the coding was checked by an independent research assistant, who was blind to the experimental hypotheses at the time of coding the video, before further analyses. The research assistant checked a sample of 10% of the coding and found that her result was 100% consistent with the result from the experimenter. Therefore, it was assumed that the rest of the data were also accurately coded. Based on the video, all the English monolinguals were right-handed; however, since the task was long and some of the participants switched hands during the task, it was impossible to know the bilinguals' handedness. Therefore, handedness was not tested. Categorized results were analysed by using R. The participants' responses for each type of word were analysed in mixed effects logistic regression models by using packages lme4 (Bates, Mächler, Bolker, & Walker, 2015) and languageR (Baayen, 2013).

Model Fitting Strategies

For the any-direction condition, the numbers of responses were first collected in order to see the primary dimension for each group of the participants. After that, data were split into three dimensions and mixed effect logistic regression models were tested on responses on each dimension. For the sagittal dimension, the first model contained word and speaker as random intercepts and the interaction between time type and language group/condition as a fixed effect. This was to look at the differences across groups. After that, for the responses from the English monolinguals and the bilinguals in the English context, preliminary models which contained the interaction between time type and English sagittal cues did not reveal any significant results,

suggesting that the four English cues, which were the results of direct translation, had no effect in English. Therefore, for both the English monolinguals and the bilinguals in the English context, models that contained word and speaker as random intercepts and time type as a fixed effect were tested on all the time-related words.

For responses from the bilinguals in the Mandarin context and the Mandarin monolinguals, the model contained the same random intercepts, and the interaction between time type and directional cues as a fixed effect. Three separate models were also tested on the combined data of the English monolinguals and the bilinguals in the English condition, the bilinguals in the two different language context, and the bilinguals in the Mandarin context and the Mandarin monolinguals. In each of the three models, the interaction between time type and language group/context was a fixed effect, and word and participant as random intercepts. These three models were tested in order to look at whether participants in different language group/context behaved differently. For responses on the other two dimensions, the same model fitting strategies were used, except that there were no English cues being tested.

For each of the sagittal-only and vertical-only conditions, a model that had the interaction between time type and language group was first tested in order to look at any differences across groups. After that, the interaction between time type and English sagittal cues was tested, however, it did not reveal any significant results. Therefore, only time type was tested for the English monolinguals for all the time-related words. For the bilinguals, the interaction between time type and language context was tested, which was in order to look at the effect of language contexts on them. Then the effect of time type was tested on the bilinguals in the English context. After that, the interaction between time type and spatial cues was tested for the bilinguals in the Mandarin context and the Mandarin monolinguals. For responses from the transverse-only condition, the interaction between time type and language was first tested. After that, the effects of time type were tested separately for each language group/condition. The three separate models were also tested in order to look at whether participants from different language group/context behaved differently.

If the interaction between time type and directional cues was not significant, a simpler model that contained time type as a fixed effect and speaker and word as random intercepts was tested.

3.3 Results

All the participants' responses (from 10 English monolinguals, 10 bilinguals in different conditions, and 10 Mandarin monolinguals) in the first condition were analyzed. The first condition was always the any-direction condition, which means the participants can point any direction they want for each word.

For each type of word, that is, 24 time related, 10 emotion related, 10 health related and 10 random paired words, differences in the numbers of responses on each dimension between groups were tested by using Wilcoxon tests. However, since the current study focuses on temporal information, only results from time-related words are reported. For time-related words, the numbers of responses are plotted in boxplot and the results of Wilcoxon tests are listed for four comparisons, which are between the English monolinguals and the bilinguals in the English condition, between the bilinguals in the English condition and in the Mandarin condition, between the bilinguals in the Mandarin condition and the Mandarin monolinguals, and between the English monolinguals and the Mandarin monolinguals. In each cell, the numbers are the results of Wilcoxon tests on rates by word and by subject respectively. Boxplots are shown for responses by word and by subject.

3.3.1 Choice of Using Different Dimensions

Table 3.5: Results of Wilcoxon tests that test differences in the numbers of responses by word and by subject between groups for time-related words.

Dimension	English monolinguals and Bilinguals in English	Bilinguals in English and in Mandarin	Bilinguals in Mandarin and Mandarin monolinguals	English monolinguals and Mandarin monolinguals
sagittal	< 0.05 /0.589	0.1925/0.3508	< 0.05 /0.1443	< 0.05 /0.304
transverse	< 0.05 /0.3996	0.0617/0.8918	< 0.05 /0.1197	< 0.05 /0.5242
vertical	< 0.05 /0.6414	0.189/0.2008	< 0.05 /0.153	< 0.05 / <0.05

Wilcoxon tests by word and by subject show very different results. There was only one significant difference when conducting Wilcoxon tests by subject, which was between the English monolinguals and the Mandarin monolinguals on the vertical dimension. The Mandarin monolinguals produced more vertical responses than the English monolinguals. However, when conducting Wilcoxon tests by word, Table 3.5 reveals that there were differences on all the three dimensions for each comparison except for the one for the bilinguals between the two language contexts. The numbers of responses by word are plotted in Figure 3.1.

Figure 3.1: Boxplots for the numbers of responses by word on each dimension for time-related words in each group, b: bilinguals, m: monolinguals, light grey: sagittal responses, dark grey: vertical responses, white: transverse responses.

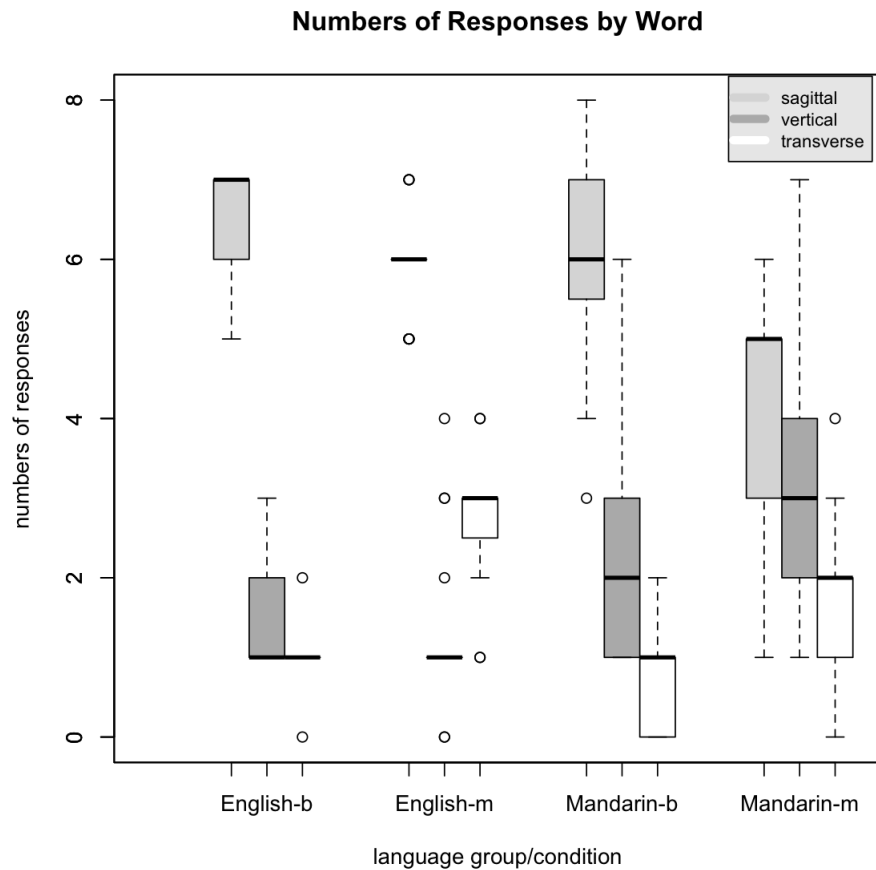
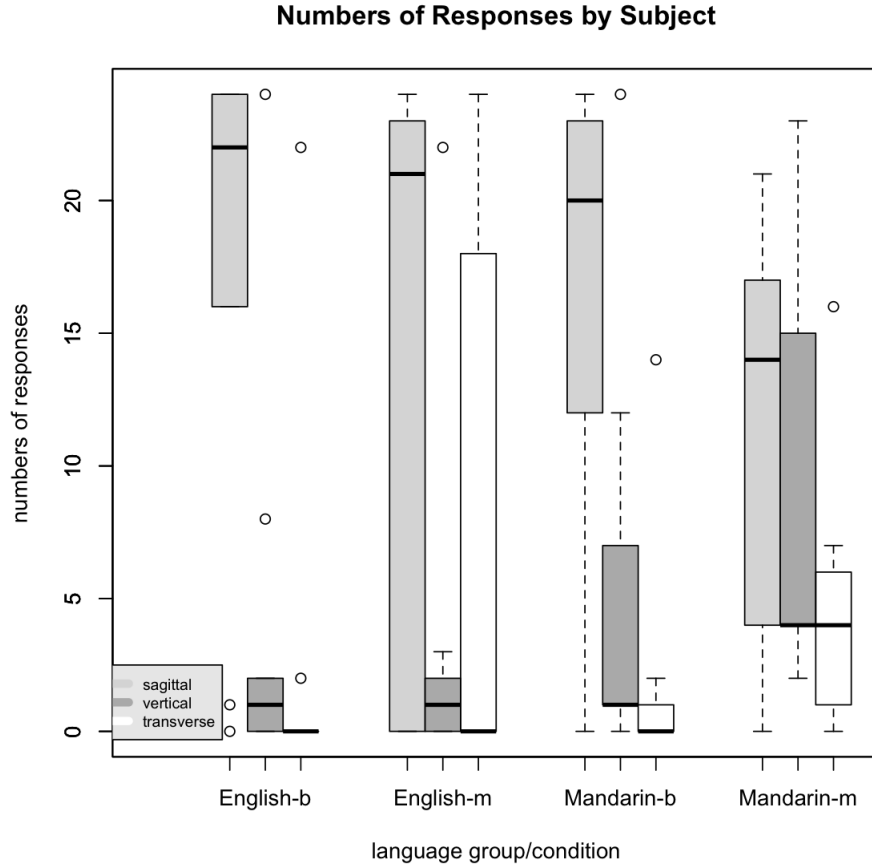


Figure 3.1 is based on the number of responses by word on each dimension in each group of speakers when there were no restrictions, and there were significant differences between groups on each dimension. When comparing the bilinguals in the English condition with the English monolinguals, it showed that the bilinguals in the English condition used the three dimensions significantly differently from the English monolinguals: the former used the sagittal and the vertical dimensions more often, and used the transverse dimension less often than the latter. There were significant differences between the English monolinguals and the Mandarin monolinguals; the Mandarin monolinguals used the vertical dimension more often than the English monolinguals. The Mandarin monolinguals also used the sagittal and transverse dimensions

less often than the English monolinguals. The Mandarin monolinguals used the vertical and transverse dimensions more often, and used the sagittal dimension less often than the bilinguals in the Mandarin condition. The plot also shows that the Mandarin monolinguals, and the bilinguals in the Mandarin and English conditions used the sagittal dimension more often than using the vertical, and used the vertical dimension more often than using the transverse. The English monolinguals were the only group that used the transverse dimension more often than the vertical.

Figure 3.2 is based on the numbers of responses by subject on each dimension in each language group when there are no restrictions. There was only one significant difference, which was between the English monolinguals and the Mandarin monolinguals on the vertical dimension. The plot shows that the Mandarin monolinguals used the vertical dimension more frequently than the English monolinguals; however, there were no significant differences on the sagittal dimension between the English and Mandarin conditions. It is also worth noting that the Mandarin monolinguals used the sagittal dimension more than the vertical. Such a fact is also shown in Figure 3.1. Also note that the English monolinguals used the transverse dimension more often than using the vertical. Both figures show that the English monolinguals used the transverse dimension more often than other groups, whereas the Mandarin monolinguals used the vertical dimension more often than other groups. Both figures also show that the English monolinguals used the sagittal dimension more often than using the transverse dimension.

Figure 3.2: Boxplots for the numbers of responses by subject on each dimension for time-related words in each group, b: bilinguals, m: monolinguals, light grey: sagittal responses, dark grey: vertical responses, white: transverse responses.



Data from the any-direction condition were split into three different groups according to different dimensions. For responses on each dimension, including the any-direction condition and the restricted conditions, logistic regression models were first tested on the overall data across the four language groups/conditions, which was in order to see the differences between language groups. After that, different language groups were analyzed separately, which was to test the effect of time type and spatial cues. The order of the result section will be as follows:

I will first present results for responses on the sagittal dimension, followed by results on the vertical dimension and then those on the transverse dimension. For results in each dimension, I will first present results

from the any-direction condition, including results from the four language groups/condition, and after that I will present results on the corresponding dimension from the restricted conditions, also including results from the four language groups/conditions. When presenting results for Mandarin-speaking groups, the results of the effect of spatial cues will also be presented.

3.3.2 Results from the Sagittal Dimension

3.3.2.1 Sagittal Responses from the Any-direction Condition

A mixed effect logistic regression model was first tested on the participants' sagittal responses from the any-direction condition. The results are given in Table 3.6.

Table 3.6: The results of the model testing the interaction between time type and language for the participants' sagittal responses in the any-direction condition, b:bilinguals, m :monolinguals, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	0.8657	0.3241	2.671	<0.01	**
language=English-m	2.7899	0.7951	3.509	<0.001	***
language=Mandarin-b	-1.1092	0.3661	-3.03	<0.01	**
language=Mandarin-m	-1.6883	0.4631	-3.646	<0.001	***
time type=past	-2.645	0.4507	-5.869	<0.001	***
language=English-m:time type=past	-5.4239	1.3049	-4.157	<0.001	***
language=Mandarin-b:time type=past	0.5325	0.6221	0.856	0.392028	
language=Mandarin-m:time type=past	3.5848	0.6145	5.834	<0.001	***

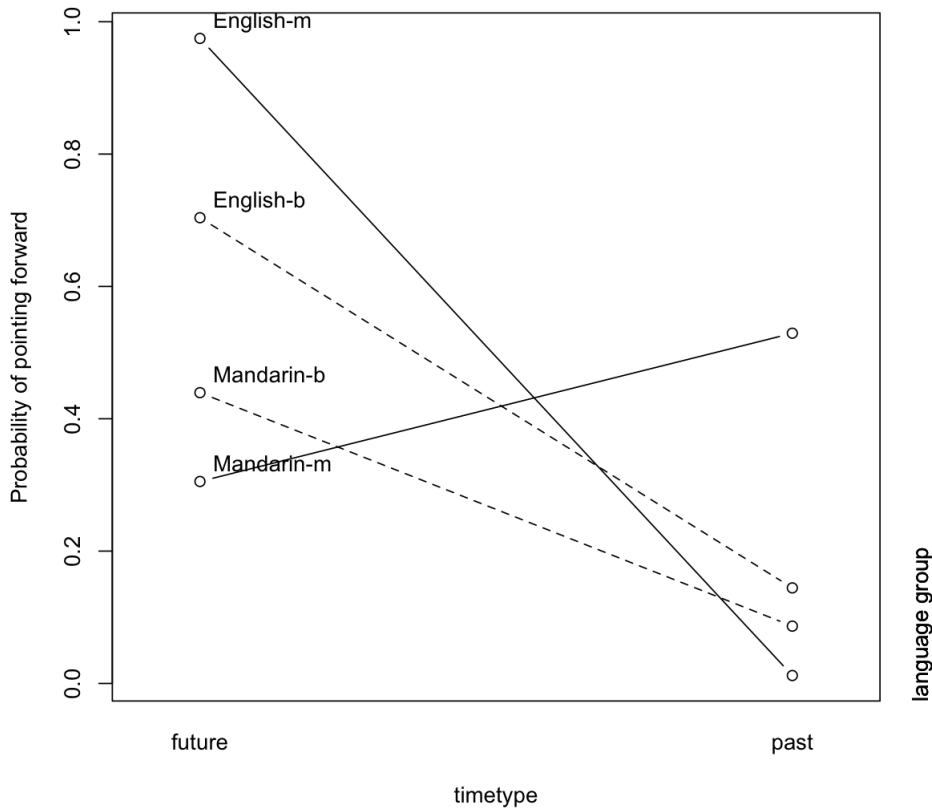
Table 3.6 shows a significant interaction between language and time type ($p < .001$). The complex result can be better understood when plotted. The plot is shown in Figure 3.3.

It shows that when choosing to give sagittal responses, the English monolinguals mostly associated front with the future, and back with the past. One-proportion z-tests were conducted¹. It suggested that the English monolinguals' responses as front for the future were greater than chance performance ($z = 7.825$) and their responses as back for the past were greater than chance

¹ These tests might not be suitable when testing responses across participants and across items since they might inflate Type I error; however, they are provided for people who are unfamiliar with logistic regression models.

performance ($z = 8.305$). The bilinguals in the English context showed similar patterns to the English monolinguals; however, the associations between front and the future and between back and the past were not as strong as those from the English monolinguals. In the English context, the bilinguals' sagittal responses as front for the future were greater than chance performance ($z = 3.292$) and their responses as back for the past were greater than chance performance ($z = 6.176$).

Figure 3.3: Plot for the results of the model testing the interaction between language group and time type for the participants' responses on the sagittal dimension in the any-direction condition, b/dashed line: bilinguals, m/solid line: monolinguals.



The bilinguals in the Mandarin condition seemed to have no preference to associate the future with either front or back and they mostly associated back with the past. Their sagittal responses for the future were not different from chance performance ($z = -0.944$), and their sagittal responses as back for the

past were greater than chance performance ($z = 6.905$). For the Mandarin monolinguals, they mostly associated back with the future, and they seemed to have no preference to associate the past with either front or back, and such a fact is also revealed when conducting one-proportion z-tests. The Mandarin monolinguals' sagittal responses for the past were not different from chance performance ($z = -0.288$), and their sagittal responses as back for the future were greater than chance performance ($z = 2.546$).

English monolinguals

When looking at the English monolinguals' sagittal responses for all the temporal words, time type (i.e. future vs. past) was tested. There was a significant difference in responses between the future and the past. The result of the model shows that the effect of time type was significant (estimate value -79.38 , $p < 0.001$). The result reveals that time type had a significant effect on the English monolinguals when they chose to point sagittally in the any-direction condition. The negative estimated value shows that when they chose to point sagittally they pointed back more often for the past than for the future.

Bilinguals in the English Context

A separate model was tested only on the English monolinguals and the bilinguals in the English condition, and the results show that, although the two groups seemed to show similar patterns, they were significantly different from each other ($p < 0.001$).

For the bilinguals in the English context, there was a significant difference in responses between the future and the past. Time type was also tested for the bilinguals in the English condition, and it had a significant effect on them. The model shows that the effect of time type was significant (estimate value -2.4902 , $p < 0.001$) for the bilinguals in the English condition when they chose to point sagittally in the any-direction condition. The negative estimated value shows that when they chose to point sagittally they pointed back more often for the past than for the future.

Bilinguals in the Mandarin Context

A separate model was conducted to test the interaction between time type and language context for the bilinguals, however, the interaction was not significant. It means that overall the bilinguals did not behave differently in the two different language contexts.

For the bilinguals in the Mandarin condition, there was a near-significant difference in responses between the future and the past. When conducting a separate model for the bilinguals in the Mandarin condition, the interaction between sagittal cues and time type was tested and the interaction was found to be significant ($p < 0.05$). The results are given in Table 3.7.

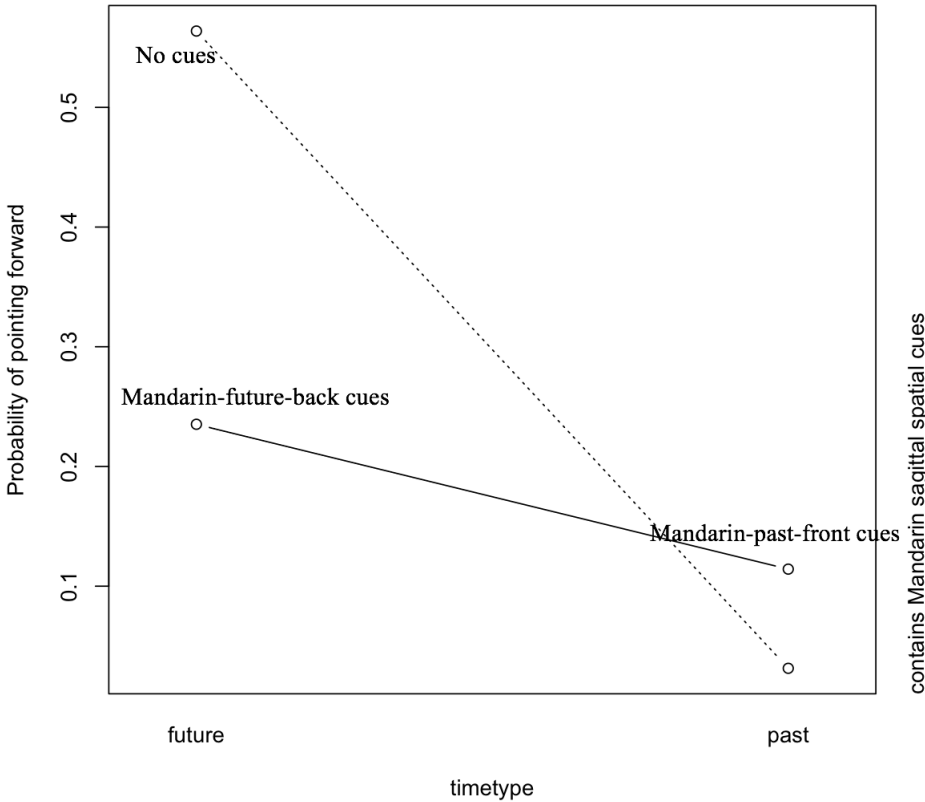
Table 3.7: The results of the model testing the interaction between time type and Mandarin sagittal directional cues for the bilinguals in the Mandarin condition when they gave sagittal responses in the any-direction condition, yes: there were cues, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	0.2564	0.5321	0.482	0.6299	
Time type=past	-3.6861	0.9006	-4.093	<0.001	***
Contains sagittal cues in Mandarin =yes	-1.4353	0.6219	-2.308	<0.05	*
Time type=past:contains sagittal cues in Mandarin =yes	2.8168	1.1316	2.489	<0.05	*

The significant interaction in Table 3.7 is plotted in Figure 3.4. It reveals that in the Mandarin condition when the bilinguals chose to give sagittal responses, they pointed back more often for the future when words contained Mandarin-future-back cues than when words did not contain them, and they pointed back less often for the past when words contained Mandarin-past-front cues than when there were no cues. Conducting analysis on subsets of the data, for future-related words, there was a near-significant difference between words that contained sagittal directional cues and words which did not have cues ($p < 0.1$); however, there was no difference for past-related words. It is also worth mentioning that the association between front and the future when there were no cues was not too strong if we look at the number on the y-axis, which is approximately 0.6. When conducting one-proportion z-tests for the four points in Figure 3.4, only their sagittal responses for the

future when there were no cues were not different from chance performance ($z = 0.949$). Sagittal cues clearly had effects on their responses. They pointed back for the past more often than for the future, and they pointed front less often for the future and pointed back less often for the past when there were sagittal cues.

Figure 3.4: Plot for the results of the model testing the interaction between time type and Mandarin sagittal cues for the bilinguals in the Mandarin condition when they gave sagittal responses in the any-direction condition. Dashed line: when temporal words contained no directional cues, solid line: when temporal words contained directional cues.



Mandarin Monolinguals

A separate model was tested on the combined data of the Mandarin monolinguals and the bilinguals in the Mandarin condition, and the model tested the interaction between time type and language group. The interaction was

significant ($p < 0.001$), which means that the bilinguals in the Mandarin condition behaved significantly differently from the Mandarin monolinguals.

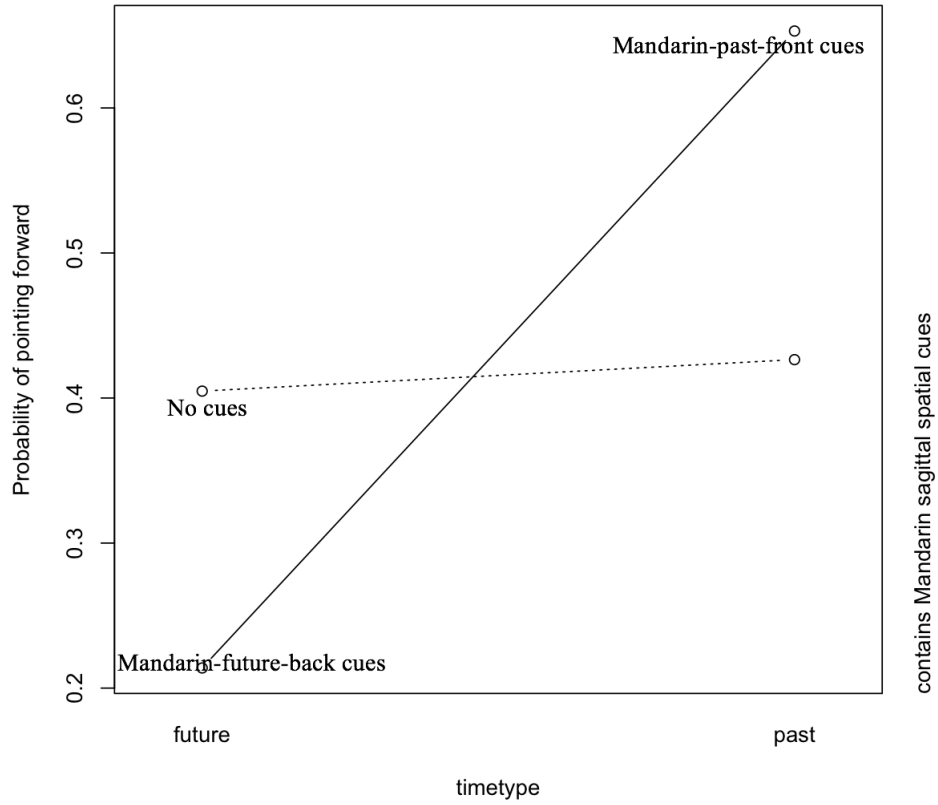
For the Mandarin monolinguals, the difference in responses between the future and the past was not significant for their sagittal responses. A separate model that tested the interaction between time type and Mandarin sagittal cues was conducted and the interaction was significant ($p < 0.05$). The results of the model are given in Table 3.8.

Table 3.8: The results of the model testing the interaction between time type and Mandarin sagittal directional cues for the Mandarin monolinguals when they gave sagittal responses in the any-direction condition, yes: there were cues, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.3857	0.4134	-0.933	0.3509
Time type=past	0.0894	0.5524	0.162	0.8714
Contains sagittal cues in Mandarin=yes	-0.916	0.6451	-1.42	0.1556
Time type=past:Contains sagittal cues in Mandarin=yes	1.8447	0.8921	2.068	<0.05 *

Table 3.8 shows a significant interaction between time type and Mandarin sagittal cues. The interaction is plotted in Figure 3.5. It reveals that when the Mandarin monolinguals chose to give sagittal responses in the any-direction condition, they pointed back more often for the future when temporal words contained Mandarin-future-back cues than when there were no such cues, and they pointed front for the past more often when temporal words contained Mandarin-past-front cues than when there were no such cues. When there were no spatial cues, they seemed to have no preference for either the future or the past. Results of one-proportion z-tests show that when there were cues, their sagittal responses as back for the future were greater than chance performance ($z = 2.711$), and those as front for the past were not different from chance performance ($z = 1.342$). However, their sagittal responses were not different from chance performance when there were no cues ($z = 0.962$ and 0.756 for the future and the past respectively).

Figure 3.5: Plot for the results of the model testing the interaction between time type and Mandarin sagittal cues for the Mandarin monolinguals when they gave sagittal responses in the any-direction condition. Dashed line: when temporal words contained no directional cues, solid line: when temporal words contained directional cues.



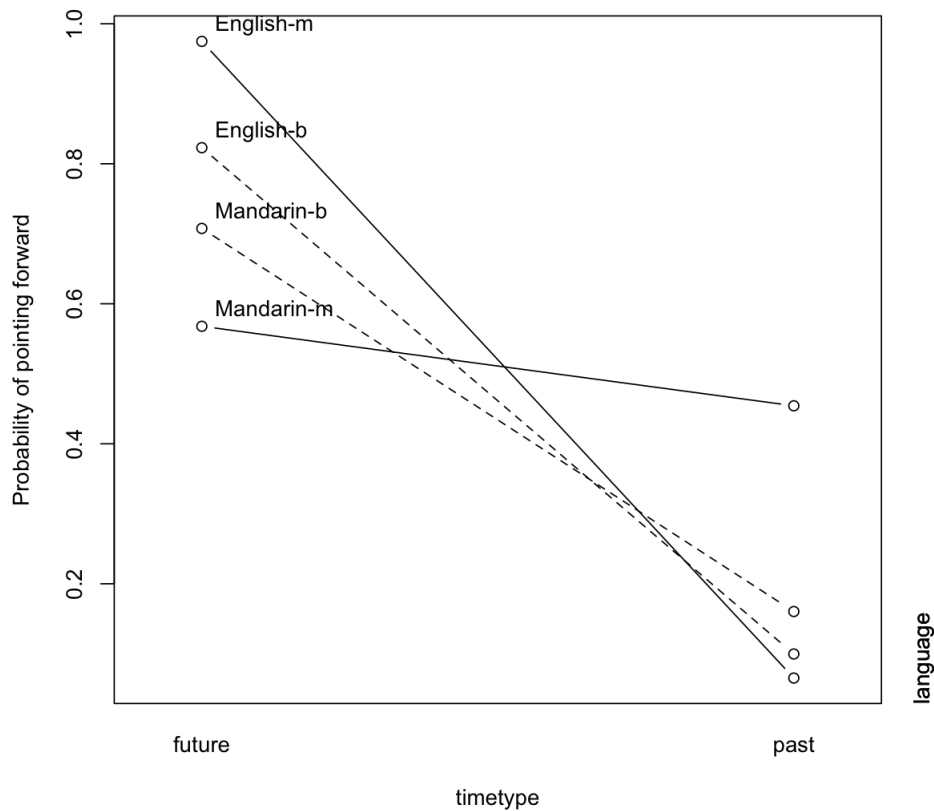
3.3.2.2 Sagittal Responses from the Sagittal-only Condition

In one of the three restricted conditions, the participants were asked to point only front and back for all the stimuli. For the data, the interaction between time type and language group was tested. This model was only for the participants' responses of time-related words in the 'front-back only' (sagittal-only) condition. The results of the model are given in Table 3.9. It shows that there is a significant interaction between language and time type ($p < 0.001$). The significant interaction is plotted in Figure 3.6.

Table 3.9: The result of the model testing responses in the sagittal-only condition across three groups, b: bilinguals, m: monolinguals, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	1.5367	0.3534	4.349	<0.001	***
language=English-m	2.1201	0.6176	3.433	<0.001	***
language=Mandarin-b	-0.6528	0.3324	-1.964	<0.05	*
language=Mandarin-m	-1.2635	0.3945	-3.203	<0.01	**
time typepast	-3.7374	0.4775	-7.826	<0.001	***
language=English-m:time typepast	-2.58	0.7382	-3.495	<0.001	***
language=Mandarin-b:time typepast	1.198	0.5169	2.318	<0.05	*
language=Mandarin-m:time typepast	3.2808	0.4882	6.72	<0.001	***

Figure 3.6: Plot for the results of the model testing responses in the sagittal-only condition across three groups, b/dashed line: bilinguals, m/solid line: monolinguals.



When comparing the bilinguals' results between the two languages in each time type, that is, within 'future' and 'past', it shows that there was a signif-

icant difference in their responses to future-related words between in English and in Mandarin ($p < 0.05$); however, the difference was only near-significant ($p < 0.1$) for past-related words. There was also a significant difference between the future and the past for both the English monolinguals and the bilinguals ($p < 0.001$). Comparison was also made between patterns in each condition and chance performance by using one-proportion z-tests. The English monolinguals' responses as front for the future were greater than chance performance ($z = 10.225$), and their responses as back for the past were also greater than chance performance ($z = 9.129$). In the English condition the bilinguals' responses as front for the future were greater than chance performance ($z = 6.158$) and their responses as back for the past were also greater than chance performance ($z = 7.89$). In the Mandarin condition, the bilinguals' responses as front for the future were greater than chance performance ($z = 3.849$) and their responses as back for the past were also greater than chance performance ($z = 6.543$). However, the Mandarin monolinguals' responses for both the future and the past were not different from chance performance ($z = 1.277$ and -0.914 for the future and the past respectively).

In order to look at how the participants in each group behaved, separate models were tested for each group of the participants.

English monolinguals

There was a significant difference between the future and the past for the English monolinguals. The results of the model showed that time type had a significant (estimate value -7.2008 , $p < 0.001$) effect on the English monolinguals. The negative estimated value shows that the English monolinguals pointed back more often for the past than for the future.

Bilinguals in the English Context

A separate model was tested only on the English monolinguals and the bilinguals in the English condition, and the results show that they were significantly different from each other ($p < 0.001$).

For the bilinguals in the English context, there was also a significant

difference between the future and the past. When testing their responses in a model, time type was included as a fixed effect, and the results reveal that time type had a significant effect on the bilinguals' perception of time in the English context on the sagittal dimension (estimate -3.4531, $p < 0.001$). The negative estimated value means that they pointed back more often for the past than for the future.

A separate model was also tested on the bilinguals' data, which was in order to test whether the bilinguals behaved differently in the two language contexts. The model had the interaction between time type and language context as a fixed effect, and it was conducted on the bilinguals' data when their responses from the two language contexts were combined. The model showed a significant interaction ($p < 0.05$), which means that the bilinguals behaved significantly differently in the two different language contexts.

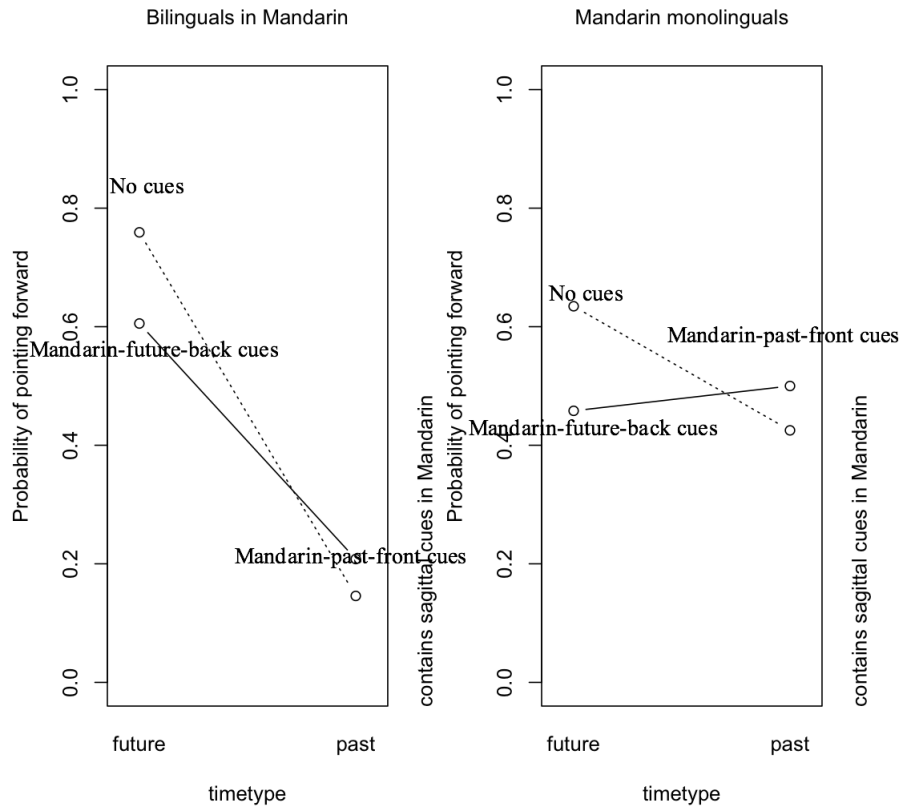
Participants in the Mandarin Context

Before testing the effect of Mandarin sagittal cues for the Mandarin monolinguals and the bilinguals in the Mandarin condition, a separate model that tested the interaction between time type and language were conducted on the combined data. The model showed a significant interaction ($p < 0.05$), which means that the Mandarin monolinguals behaved differently from the bilinguals in the Mandarin context. When testing the effect of spatial cues, logistic regression models were tested for the two groups separately. Both models tested the interaction between time type and whether there were Mandarin sagittal cues. In order to make a straightforward visual comparison, the results of the models are plotted next to each other Figure 3.7.

It is straightforward when plotting the models for testing sagittal cues for the two groups next to each other. For the bilinguals in the Mandarin condition, which is on the left, when there were no sagittal directional cues (dashed line), they pointed back more often for the past than the monolinguals (on the right). When there were sagittal directional cues they pointed back much more often for the past than the monolinguals did. When looking at future-related words, when there were no sagittal directional cues the bilinguals in the Mandarin condition pointed front more often for the fu-

ture than the monolinguals. When there were sagittal directional cues they pointed front more often for the future than the monolinguals.

Figure 3.7: Plots for the results of the models testing the interaction between time type and sagittal cues for the Mandarin monolinguals (right), and the bilinguals in the Mandarin context (left). Solid line: temporal words that contained sagittal directional cues in Mandarin, dashed line: temporal words that did not contain sagittal directional cues in Mandarin.



In other words, it seems that the bilinguals in the Mandarin condition were less affected by sagittal cues than the Mandarin monolinguals. When running models on subsets of the data, which was in order to look at the differences between each type of words across the two groups, it was found that there were significant differences between the two groups for past words with Mandarin sagittal cues and past words without them ($p < 0.05$ for both).

Bilinguals in the Mandarin Context

There was also a significant difference between the future and the past for the bilinguals in the Mandarin context ($p < 0.001$). The interaction between time type and Mandarin sagittal directional cues for the bilinguals in the Mandarin contexts is plotted on the left side in Figure 3.7. Mandarin sagittal cues had a tendency towards an interaction with time type and the effect did not reach significance, with a $p = 0.085$.

The p value shows that the interaction between language and whether the words contained Mandarin sagittal cues ('front' and 'back') had a tendency to affect how the bilinguals perceived temporal words in the Mandarin condition; however, it was not significant. Overt sagittal cues had a tendency to have an interaction with time type. Figure 3.7 shows (left) that when the words were in Mandarin, the bilinguals pointed front less often for the future when temporal words contained Mandarin-future-back cues than when they did not contain any. They pointed back less often for the past when temporal words contained Mandarin-past-front cues than when there were no cues. Conducting analysis on subsets of the data, there was a significant difference between future and past for both words that contained either sagittal directional cue in Mandarin ($p < 0.001$), and ones that contained neither ($p < 0.001$). For future-related words, there was a near-significant difference between words that contained sagittal cues and words that did not contain any ($p = 0.11$); however, there was no difference for past-related words. One-proportion z -tests were also conducted. For words without sagittal cues, their responses as front for the future were greater than chance performance ($z = 3.905$), and their responses as back for the past were also greater than chance performance ($z = 5.259$). For words with sagittal cues, their responses for the future were not different from chance performance ($z = 1.342$), and their responses as back for the past were greater than chance performance ($z = 3.727$).

Mandarin Monolinguals

The difference between the future and the past for the Mandarin monolin-

guals was not significant. Time type had a tendency to interact with whether the words contained Mandarin sagittal directional cues. P value for the interaction is 0.083, which is close to but not significant.

Figure 3.7 shows (right) that the lexical items ‘front’ and ‘back’ in Mandarin had a tendency to affect how the Mandarin monolinguals thought about time. They pointed front less often for the future when temporal words contained Mandarin-future-back cues than when they did not contain any. They pointed back less often for the past when temporal words contained Mandarin-past-front cues than when there were no cues. One-proportion z-tests were also conducted. For words without sagittal cues, their responses as front for the future were greater than chance performance ($z = 2.152$), and their responses for the past were not different than chance performance ($z = 1.195$). For words with sagittal cues, their responses for the future were not different from chance performance ($z = -0.566$) and neither were their responses for the past ($z = 0$). It is also important to note that the effect of the interaction was not significant: the monolinguals only had a tendency.

3.3.3 Results from the Vertical Dimension

3.3.3.1 Vertical Responses from the Any-direction Condition

For the participants' vertical responses from the any-direction condition, the interaction between time type and language group was tested. The results are given in Table 3.10. The table shows a significant interaction between time type and language. The result can be better understood when plotted.

Table 3.10: The results of the model testing the interaction between time type and language for the participants' vertical responses in the any-direction condition, b:bilinguals, m :monolinguals, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	2.3499	0.9309	2.524	<0.05	*
language=English-m	0.1752	1.2753	0.137	0.89073	
language=Mandarin-b	-0.3071	0.7906	-0.388	0.69771	
language=Mandarin-m	-1.1806	0.9584	-1.232	0.21801	
time type=past	-2.8738	1.1503	-2.498	<0.05	*
language=English-m:time type=past	-3.3789	1.7907	-1.887	<0.1	.
language=Mandarin-b:time type=past	1.013	1.2	0.844	0.3986	
language=Mandarin-m:time type=past	3.5079	1.1825	2.966	<0.01	**

Figure 3.8: Plot for the results of the model testing the interaction between language group and time type for the participants' responses on the vertical dimension in the any-direction condition, b/dashed line: bilinguals, m/solid line: monolinguals.

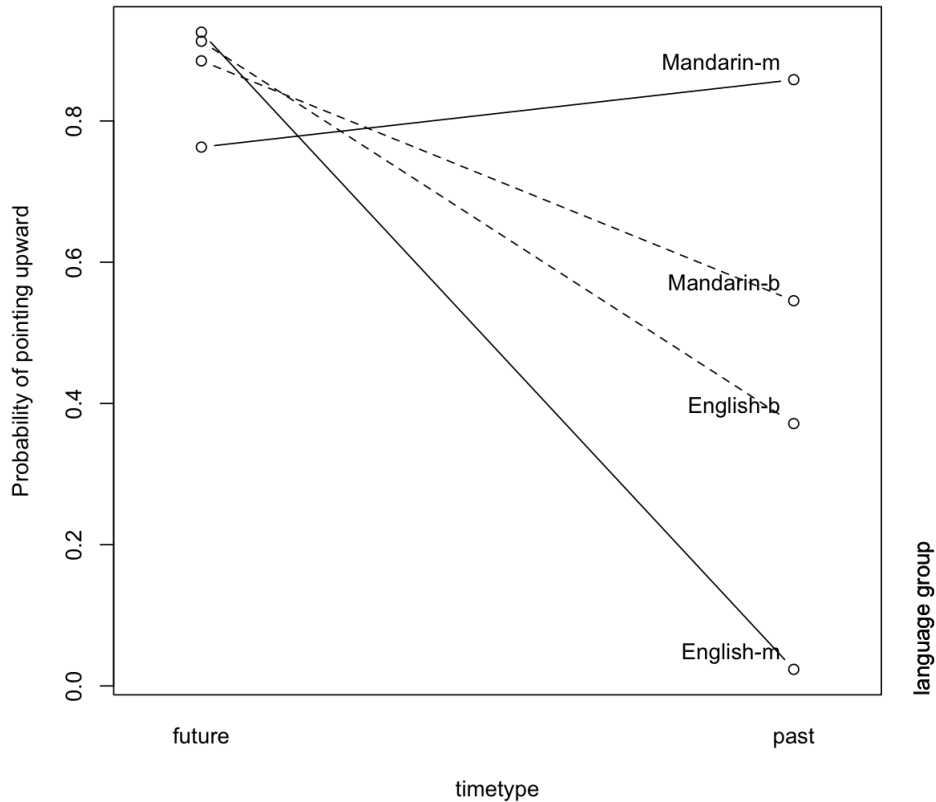


Figure 3.8 shows that the English monolinguals strongly associated up with the future and down with the past. One-proportion z-tests were conducted. It showed that their responses as up for the future were greater than chance performance ($z = 2.84$) and their responses as down for the future were also greater than chance performance ($z = 3.356$). The bilinguals in the English condition also strongly associated up with the future; however, their association between down and the past was weaker than the one from the English monolinguals. In the English context, the bilinguals' vertical responses as up for the future were greater than chance performance ($z = 2.293$), and their responses as down for the past were also greater than chance performance ($z = 1.807$). The bilinguals in the Mandarin context also strongly associated up with the future; however, their association between down and the past

was weak. In the Mandarin context, the bilinguals' vertical responses as up for the future were greater than chance performance ($z = 1.8$), and their responses for the past were not different from chance performance ($z = -0.393$). For the Mandarin monolinguals, their association between up and the past was strong; however, they mostly associated up with the future. The Mandarin monolinguals' vertical responses as up for the future were greater than chance performance ($z = 1.808$), and their responses as up for the past were also greater than chance performance ($z = 4.111$).

English monolinguals

There was a significant difference between the future and the past for the English monolinguals. Time type was found to be significantly affecting the English monolinguals when they chose to respond vertically (estimate value -39.94 , $p < 0.001$). A negative estimated value shows that when they chose to point vertically they pointed down more often for the past than for the future.

Bilinguals in the English Context

A separate test was carried out on the combined data of the English monolinguals and the bilinguals in the English context, and it tested the interaction between time type and language group. The interaction was near-significant ($p = 0.079$), which means that the bilinguals in the English context had a tendency to behave differently from the English monolinguals.

For the bilinguals in the English context, there was a significant difference between the future and the past. When testing data in a regression model, only time type was included as a fixed effect and it was found to be significant (estimate value -2.1213 , $p < 0.05$). A negative estimated value (-2.1213) shows that when they chose to point vertically they pointed down more often for the past than for the future.

Bilinguals in the Mandarin Context

A separate model was tested on the combined data from the bilinguals, which was in order to test the interaction between time type and language context. However, the interaction was not significant, which means that overall the bilinguals did not behave differently in the two language contexts.

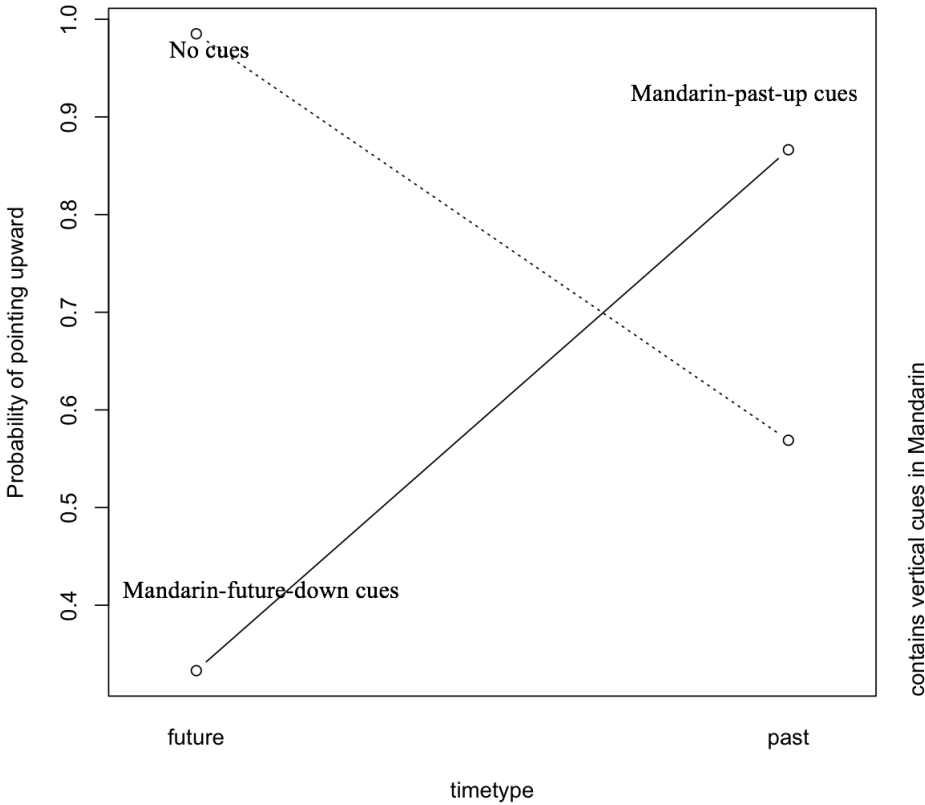
For the bilinguals in the Mandarin condition, the difference between the future and the past was not significant. When testing their vertical responses in a regression model, time type and vertical cues were tested. The model contained the interaction between time type and vertical cues as a fixed effect. The results are given in Table 3.11.

Table 3.11: The results of the model testing the interaction between time type and Mandarin vertical directional cues for the bilinguals in the Mandarin condition when they gave vertical responses in the any-direction condition, yes:there were cues, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	4.195	1.598	2.626	<0.01	**
Time type=past	-3.917	1.342	-2.918	<0.01	**
Contains vertical cues in Mandarin=yes	-4.889	1.669	-2.929	<0.01	**
Time type=past:contains vertical cues in Mandarin=yes	6.481	1.885	3.439	<0.001	***

The model had a significant interaction between time type and vertical directional cues in Mandarin. The result is plotted in Figure 3.9. It shows that when the bilinguals in the Mandarin condition chose to give vertical responses and when time-related words had no vertical directional cues, they pointed up for the future more often than for the past. One-proportion z-tests showed that for time words without cues, their responses as up for the future were greater than chance performance ($z = 3.356$), and their responses for the past were not different from chance performance ($z = 1.387$). However, when the words contained vertical directional cues, the bilinguals were affected by the overt lexical item ‘down’ and ‘up’ in the words: it seemed they pointed up for the past more often than for the future. When the words contained vertical cues, their responses for the future were not different from chance performance ($z = 1.265$), and their responses as up for the past were greater than chance performance ($z = 1.941$).

Figure 3.9: Plot for the results of the model testing the interaction between time type and Mandarin vertical cues for the bilinguals in the Mandarin condition when they gave vertical responses in the any-direction condition. Dashed line: when temporal words contained no vertical cues, solid line: when temporal words contained vertical cues.



Mandarin Monolinguals

A separate model was tested on the combined data of the bilinguals in the Mandarin condition and the Mandarin monolinguals, which was to test the interaction between time type and language group. The model showed a significant interaction ($p < 0.05$), suggesting that the bilinguals in the Mandarin condition and the Mandarin monolinguals behaved differently.

For the Mandarin monolinguals, the difference between the future and the past was not significant. Similar models were tested on the Mandarin monolinguals' responses on the vertical dimension; and neither vertical directional cues nor time type was found to be significant. A possible reason

is that time type might have effects only when temporal words contained directional cues for the Mandarin monolinguals. As a result, the Mandarin monolinguals' responses on the vertical dimension were divided into subsets according to whether the vertical responses were for words with vertical cues. When testing responses for words with vertical cues, it was found that the data was too sparse to do reliable regression models. Therefore, responses for words with vertical cues are summarized in Table 3.12. The table gives a clear picture of their preferences on the vertical dimension.

Table 3.12: Mandarin monolinguals' vertical responses for temporal words with vertical cues in the any-direction condition.

Time type	Down	Up
Future	9	3
Past	0	16

Table 3.12 shows that in the any-direction condition when the Mandarin monolinguals gave vertical responses for temporal words with vertical cues, they mostly pointed down for the future and up for the past since the words contained Mandarin-future-down cues and Mandarin-past-up cues respectively.

3.3.3.2 Vertical Responses from the Vertical-only Condition

Mixed effect logistic regression models were also tested on the participants' responses from the vertical-only condition. To look at the general differences between groups, the model contained speaker and word as two random intercepts, and the interaction between language and time type as a fixed effect. The results of the model are given in Table 3.13.

Table 3.13: The result of the model testing responses in the vertical-only condition across three groups, b: bilinguals, m: monolinguals, time type: future vs. past.

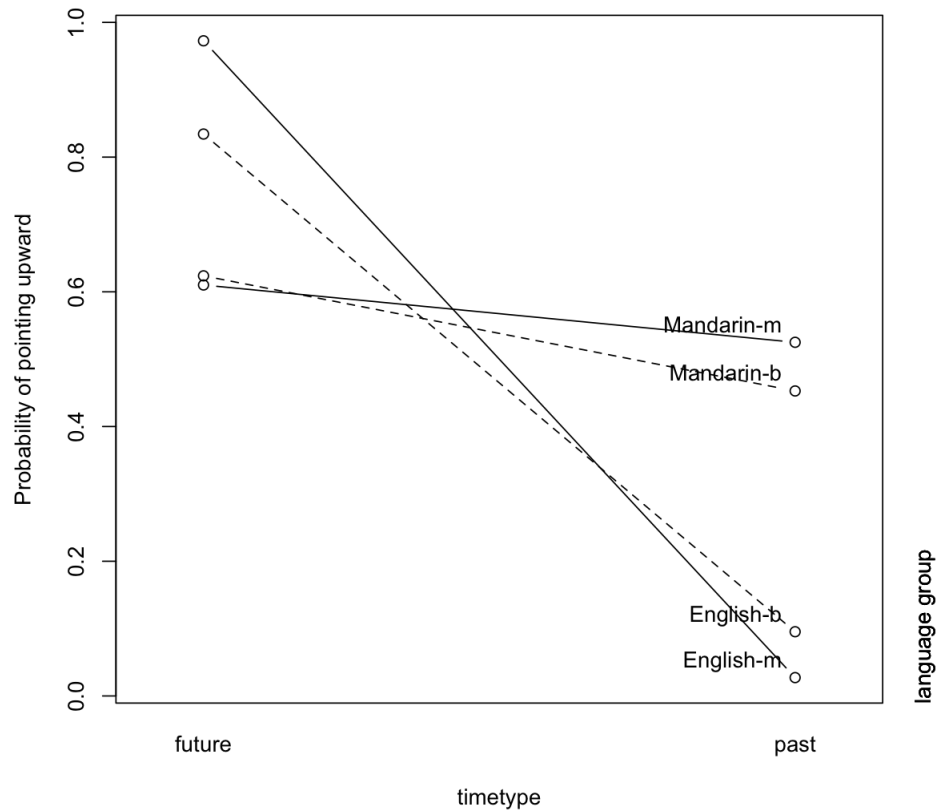
	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	1.6154	0.4169	3.875	<0.001	***
language=English-m	1.9577	0.6256	3.129	<0.01	**
language=Mandarin-b	-1.1112	0.3351	-3.316	<0.001	***
language=Mandarin-m	-1.1692	0.4612	-2.535	<0.05	*
time type=past	-3.8654	0.5296	-7.299	<0.001	***
language=English-m:time type=past	-3.2831	0.796	-4.124	<0.001	***
language=Mandarin-b:time type=past	3.1716	0.5158	6.149	<0.001	***
language=Mandarin-m:time type=past	3.5202	0.5105	6.896	<0.001	***

On the vertical dimension, there was a significant interaction between language and time type. There was also a significant difference between future and past for the English monolinguals, the bilinguals in the English condition and the bilinguals in the Mandarin condition ($p < 0.001$). The difference between future and past for the Mandarin monolinguals was not significant. The complex result can be best understood when plotted. The interaction is shown in Figure 3.10.

The English monolinguals strongly associated up with the future and down with the past. Results of one-proportion z-tests showed that their responses as up for the future were greater than chance performance ($z = 10.041$), and their responses as down for the past were also greater than chance performance ($z = 10.041$). For the bilinguals in the English condition, they also associated up with the future and down with the past, however, their associations were not as strong as those from the English monolinguals. Their responses as up for the future were greater than chance performance ($z = 5.965$), and their responses as down for the past were also greater than chance performance ($z = 7.699$). The bilingual speakers pointed up for the future more often in English than in Mandarin, and they pointed down for the past more often in English than in Mandarin too. When comparing the difference between English and Mandarin for each time type, that is, within ‘future’ and ‘past’, significant differences were found for past-related words, and the difference on future-related words between the bilinguals’ response in Mandarin and the Mandarin monolinguals’ responses was not significant. The bilinguals in the Mandarin condition and the Mandarin monolinguals

seemed to have no preference to associate the future and the past with either up or down.

Figure 3.10: Plot for the results of the model testing responses in the vertical-only condition across three groups, b/dashed line: bilinguals, m/solid line: monolinguals.



Comparisons were also made between responses in each condition and chance performance for the bilinguals in the Mandarin context and the Mandarin monolinguals. When in the Mandarin condition, the bilinguals' responses as up for the future were greater than chance performance ($z = 1.9585$) and their responses for the past were not different from chance performance ($z = 0.9664$). The Mandarin monolinguals' responses as up for the future were greater than chance performance ($z = 1.825$) and their responses for the past were not different from chance performance ($z = 0.366$).

Vertical directional cues in the materials were also tested. Directional cues refer to overt spatial information that is embedded in temporal words.

In the current study on the vertical dimension the directional cues that were tested were the spatial words that indicate either ‘up’ or ‘down’ in Mandarin. As mentioned, ‘up’ and ‘down’ in Mandarin are addressed as Mandarin-past-up cue and Mandarin-future-down cue respectively.

English monolinguals

There was a significant difference between the future and the past for the English monolinguals. When testing the English monolinguals' responses on the vertical dimension, the model contained speaker and word as random intercepts and time type as a fixed effect. The result reveals a significant effect of time type on the English monolinguals' vertical responses (estimate value -8.799, $p < 0.001$). The negative estimated value shows that when being forced to give vertical responses, the English monolinguals pointed down more often for the past than for the future.

Bilinguals in the English Context

A separate model was tested on the combined data of the English monolinguals and the bilinguals in the English condition. The model showed a significant interaction ($p < 0.001$) between time type and language group, suggesting that the bilinguals in the English condition behaved significantly differently from the English monolinguals.

There was a significant difference between the future and the past for the bilinguals in the English context. When testing their responses in a regression model, time type was tested as a fixed effect, and the model revealed a significant effect of time type on the bilinguals in the English context when they gave vertical responses (estimate value -4.2351, $p < 0.001$). The negative estimated value shows that when being forced to give vertical responses, the bilinguals in the English condition pointed down more often for the past than for the future.

A separate model was tested on the combined data of the bilinguals in the English context and the bilinguals in the Mandarin context. The model showed a significant interaction between time type and language context

($p < 0.001$), suggesting that the bilinguals behaved differently in the two language contexts.

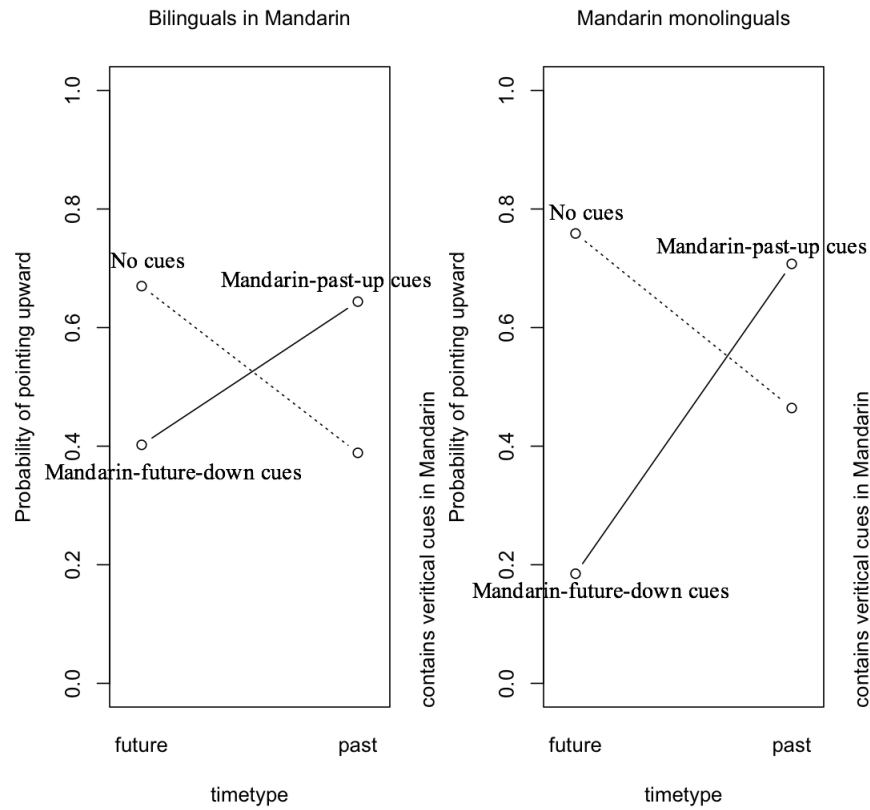
Participants in the Mandarin Context

Another separate model was tested on the combined data of the bilinguals in the Mandarin context and the Mandarin monolinguals. However, the interaction between time type and language group was not significant, suggesting that the bilinguals in the Mandarin context and the Mandarin monolinguals did not behave differently.

When testing the effect of Mandarin vertical cues for the Mandarin monolinguals and the bilinguals in the Mandarin condition, logistic regression models were tested for the two groups separately. Both models tested the interaction between time type and whether there were Mandarin vertical cues. In order to make a straightforward visual comparison, the results of models are plotted next to each other in Figure 3.11.

Figure 3.11 reveals that the Mandarin monolinguals responses were similar to the bilinguals' responses in the Mandarin condition when temporal words had no vertical directional cues. When the words contained vertical directional cues, the Mandarin monolinguals pointed down for the future more often than the bilinguals in the Mandarin condition, which means that the former seemed to be more affected by the overt Mandarin-future-down cues. However, when testing subsets of combined data, no significant differences were found between the two groups, which means that the Mandarin monolinguals and the bilinguals in the Mandarin condition did not have significant differences.

Figure 3.11: Plots for the results of the models testing the interaction between time type and vertical cues for the Mandarin monolinguals (right), and the bilinguals in the Mandarin context (left). Solid line: temporal words that contained sagittal directional cues in Mandarin, dashed line: temporal words that did not contain vertical directional cues in Mandarin.



Bilinguals in the Mandarin Context

For the bilingual in the Mandarin context, the interaction between time type and Mandarin vertical directional cues was tested (plot on the left in Figure 3.11). The results of the model are given in Table 3.14. The results of the model show a significant interaction between time type and directional cues. Both time type and whether the words contained vertical directional cues were significant. There were significant differences between future and past for both words that contained vertical cues, and ones that did not contain any. Directional cues such as ‘up’ and ‘down’ in Mandarin words significantly affected how the bilinguals thought about time.

Table 3.14: The results of the model testing the interaction between time type and Mandarin vertical directional cues for the bilinguals in the Mandarin condition in the vertical-only condition, yes:there were cues, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	0.7078	0.3277	2.16	<0.05	*
Time type=past	-1.1604	0.3432	-3.381	<0.001	***
Contains vertical cues in Mandarin=yes	-1.1039	0.4786	-2.307	<0.05	*
Time type=past:contains vertical cues in Mandarin=yes	2.1484	0.6806	3.156	<0.01	**

In the Mandarin words, ‘up’ is associated with the past, and ‘down’ is associated with the future. It can be seen that in general, the future is considered to be ‘up’, unless there is a Mandarin-future-down cue indicating otherwise, whereas the past is considered to be ‘down’, unless there is a Mandarin-past-up cue indicating otherwise.

Results of one-proportion z-tests showed that when there were no vertical cues, their responses as up for the future were greater than chance performance ($z = 2.777$) and their responses as down for the past were also greater than chance performance ($z = 1.888$). When the words contained vertical cues, their responses for the future were not different from chance performance ($z = 0.962$) and their responses for the past were not different from chance performance ($z = 1.347$).

Mandarin Monolinguals

For the Mandarin monolinguals, the interaction between time type and vertical directional cues was tested. The results of the model are given in Table 3.15. The results in the table reveal a significant interaction between time type and directional cues. The results are plotted on the right in Figure 3.11. It reveals that when time-related words had no directional cues, the Mandarin monolinguals' pointed up for the future more often than for the past. However, when the words contained directional cues, the Mandarin monolinguals were affected by the overt vertical lexical item Mandarin-future-down cues and Mandarin-past-up cues in the words.

Table 3.15: The results of the model testing the interaction between time type and Mandarin vertical directional cues for the Mandarin monolinguals in the vertical-only condition, yes : there were cues, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	1.1457	0.496	2.31	<0.05	*
Time type=past	-1.2886	0.5566	-2.315	<0.05	*
Contains vertical cues in Mandarin=yes	-2.6294	0.8213	-3.201	<0.01	**
Time type=past:contains vertical cues in Mandarin=yes	3.6554	1.1328	3.227	<0.01	**

Results of one-proportion z-tests showed that when the words had no vertical cues, the Mandarin monolinguals' responses as up for the future were greater than chance performance ($z = 3.795$) and their responses for the past were not different from chance performance ($z = 0.632$). When the words contained vertical cues, their responses as down for the future were greater than chance performance ($z = 2.922$), and their responses as up for the past were also greater than chance performance ($z = 1.826$).

3.3.4 Results from the Transverse Dimension

3.3.4.1 Transverse Responses from the Any-direction Condition

For responses on the transverse dimension, it was found that the data were too sparse to test a reliable regression model except for the Mandarin monolinguals. Therefore, each language group/condition was analyzed separately.

English monolinguals

When looking at the distribution of transverse responses from the English monolinguals, it clearly shows the effect of time type because the English monolinguals' transverse responses were categorical. The table below gives the distribution.

Table 3.16: The English monolinguals' transverse responses for temporal words in the any-direction condition.

Time type	Left	Right
Future	0	34
Past	32	0

Table 3.16 shows that the English monolinguals pointed left for the past and right for the future exclusively.

Bilinguals in the English Context

Categorical responses were also found from the bilinguals in the English context. When looking at the distribution across different time types, time type clearly affected how they responded on the transverse dimension. Table 3.17 is a two by two table that shows the distribution of transverse responses for the bilinguals in the English context.

Table 3.17: The bilinguals' transverse responses in the English condition for temporal words in the any-direction condition.

Time type	Left	Right
Future	0	13
Past	11	0

Table 3.17 shows that the bilinguals in the English context pointed left for the past and right for the future exclusively.

Bilinguals in the Mandarin Context

Near-categorical responses were found from the bilinguals in the Mandarin context. When looking at the data, it clearly shows their preference on the transverse dimension. The table below shows the distribution of their responses.

Table 3.18: The bilinguals' transverse responses in the Mandarin condition for temporal words in the any-direction condition.

Time type	Left	Right
Future	1	9
Past	8	0

Table 3.18 shows that the bilinguals in the Mandarin context mostly pointed left for the past and right for the future.

Mandarin Monolinguals

Time type was tested as the only fixed effect in a model; however, it was not found to be significantly affecting the Mandarin monolinguals' transverse responses. The numbers of responses for each time type are given in Table 3.19.

Table 3.19: The Mandarin monolinguals' transverse responses for temporal words in the any-direction condition.

Time type	Left	Right
Future	13	8
Past	14	4

3.3.4.2 Transverse Responses from the Transverse-only Condition

Mixed effect logistic regression models were also tested on the participants' responses in the transverse-only condition. To look at the general differences between groups, the interaction between language and time type was tested. The results of the model are given in Table 3.20.

On the transverse dimension, there was a significant interaction between language and time type. There was also a significant difference between future and past for the English monolinguals, the bilinguals in the English condition, the bilinguals in the Mandarin condition and the Mandarin monolinguals. The complex result is plotted in Figure 3.20.

Table 3.20: The results of the model testing the interaction between time type and language for the participants' transverse responses in the transverse-only condition, b:bilinguals, m :monolinguals, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	0.50143	0.24198	2.072	<0.05	*
language=English-m	1.7276	0.42471	4.068	<0.001	***
language=Mandarin-b	-0.34991	0.27962	-1.251	0.2108	
language=Mandarin-m	0.04285	0.33636	0.127	0.8986	
time type=past	-1.33917	0.29109	-4.601	<0.001	***
language=English-m:time type=past	-3.22555	0.55017	-5.863	<0.001	***
language=Mandarin-b:time type=past	0.48003	0.40623	1.182	0.2373	
language=Mandarin-m:time type=past	0.48534	0.39944	1.215	0.2244	

Figure 3.12: Plot for the results of the model testing responses in the transverse-only condition across the three groups, b/dashed line: bilinguals, m/solid line: monolinguals.

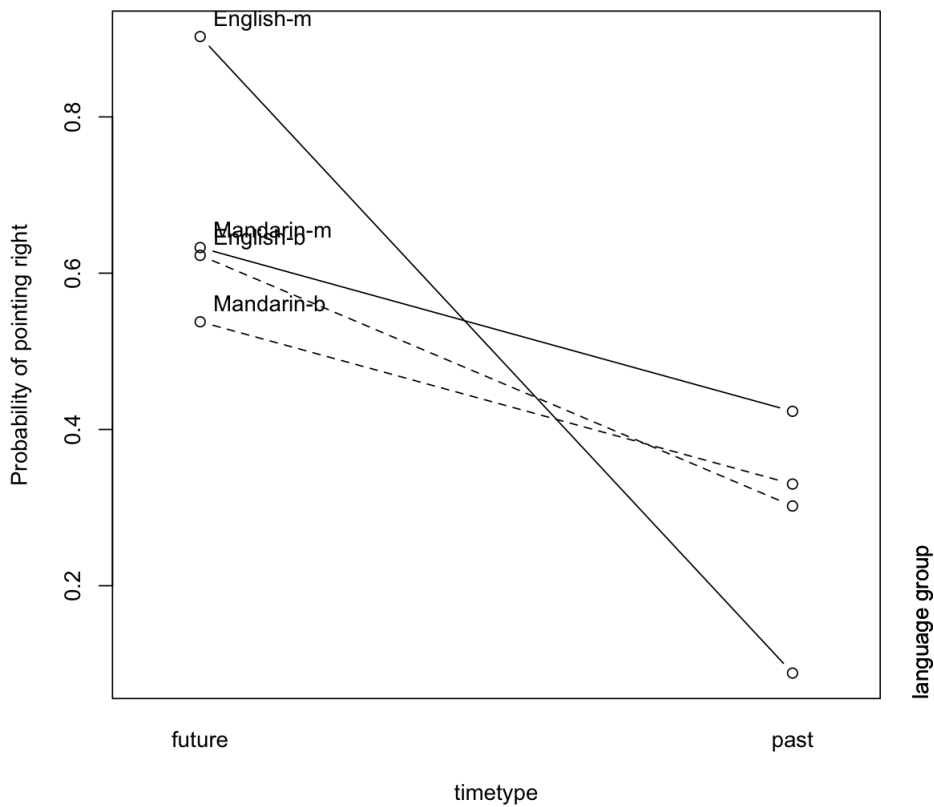


Figure 3.12 shows that the English monolinguals strongly associated right with the future and left with the past. Compared to the English monolin-

guals, the bilinguals in the English and the Mandarin condition, and the Mandarin monolinguals less often pointed right for the future and less often pointed left for the past. When testing each group separately, only time type was tested for different groups of speakers. One-proportion z-tests were also conducted. The English monolinguals' responses as left for the past were greater than chance performance ($z = 8.468$), and their responses as right for the future were also greater than chance performance ($z = 8.274$). When in the English context, the bilinguals' responses as left for the past were greater than chance performance ($z = 3.656$) and their responses as right for the future were also greater than chance performance ($z = 2.502$). When in the Mandarin context, the bilinguals' responses as left for the past were greater than chance performance ($z = 3.465$), and their responses for the future were not different from chance performance ($z = 0.769$). The Mandarin monolinguals' responses for the past were not different from chance performance ($z = 1.558$), and their responses as right for the future were better than chance performance ($z = 2.739$).

English Monolinguals

There was a significant difference between the future and the past for the English monolinguals. The model for testing the English monolinguals contained time type as a fixed effect. The results of the model reveal a significant effect of time type (estimate value -4.4592 , $p < 0.001$). The negative estimated value shows that the English monolinguals pointed left more often for the past than for the future.

Bilinguals in the English Context

A separate model was tested for the combined data of the English monolinguals and the bilinguals in the English context. The model showed a significant interaction between time type and language group ($p < 0.001$), suggesting that the English monolinguals and the bilinguals in the English context behaved significantly differently.

There was a significant difference between the future and the past for

the bilinguals in the English context. The results of the model testing the bilinguals' responses in the English context show a significant result (estimate value -1.3121, $p < 0.001$). The negative estimated value means that the bilinguals in the English condition pointed left more often for the past than for the future.

Bilinguals in the Mandarin Context

A separate model was tested on the combined data of the bilinguals in the two language contexts. However, the interaction between time type and language context was not significant, suggesting that the bilinguals did not behave differently in the two different language contexts.

There was a significant difference between the future and the past for the bilinguals in the Mandarin context. The model for testing the bilinguals in the Mandarin context also shows a significant effect of time type (estimate value -0.8425, $p < 0.01$). The negative estimated value indicates that the bilinguals in the Mandarin context pointed left more often for the past than for the future.

Mandarin Monolinguals

A separate model was tested on the combined data of the bilinguals in the Mandarin context and the Mandarin monolinguals. However, the interaction between time type and language context was not significant, suggesting that the bilinguals in the Mandarin context did not behave differently from the Mandarin monolinguals.

For the Mandarin monolinguals, there was a significant difference between the future and the past for the Mandarin monolinguals. The results of the model show a significant effect of time type (estimate value -0.951, $p < 0.01$). The negative estimated value indicates that the Mandarin monolinguals pointed left more often for the past than for the future.

3.3.5 *Correlation between the Sagittal and Vertical Dimensions*

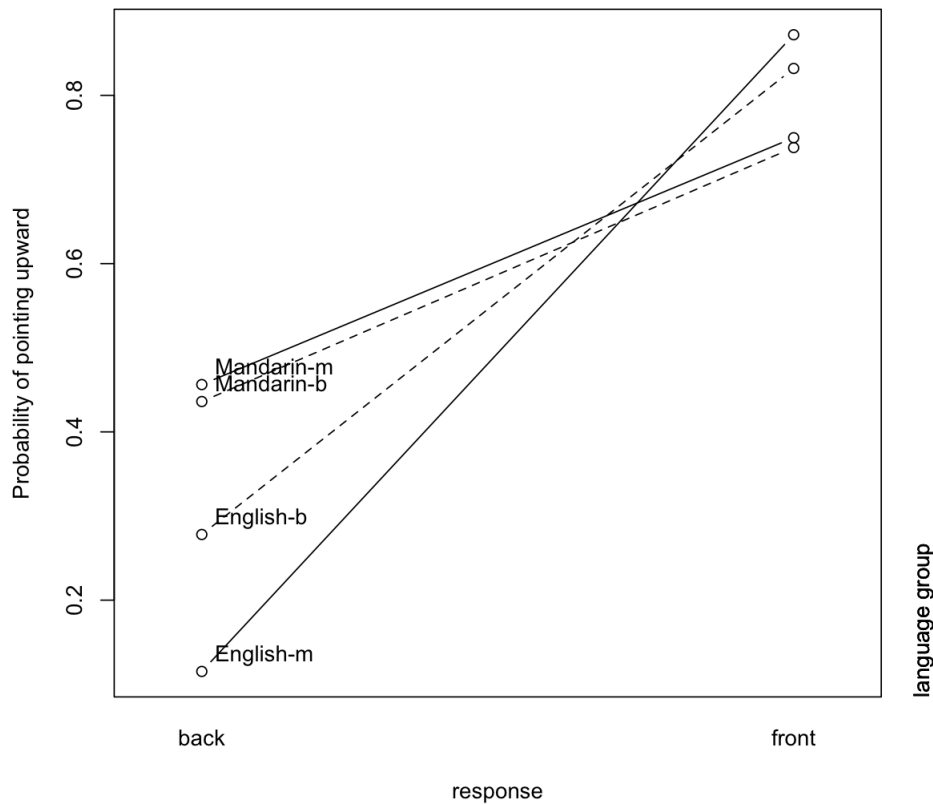
As mentioned earlier, the English monolinguals and the bilinguals in the English condition associated the future with up. English has no observable preference in spatio-temporal metaphors in associating time with directions on the vertical dimension, that is, FUTURE IS UP. However, the FUTURE IS UP metaphor is indirectly connected between FUTURE IS GOOD and GOOD IS UP. However, it might also be because that the association between time and direction on the vertical dimension found in English might be a projection from the association between time and direction on the sagittal dimension. If the vertical preference patterns stem from the sagittal preferences, I then predicted that English would show a stronger correlation between the two dimensions than Mandarin even for the words that do not have spatial information. As a result, the correlation between the frequencies of pointing up and pointing front for the participants was also tested. After removing all the words which had spatial directions, that is, “front”, “back”, “up” and “down”, Spearman's correlation tests were conducted. Spearman's correlations on the English monolinguals, the bilinguals in the English context and in the Mandarin context, and the Mandarin monolinguals were 0.931, 0.881, 0.764 and 0.760 respectively. When testing the differences between correlations, the Fisher r -to- z transformation was used and it was found that there were significant differences between them: $z = 1.68$ and $p = 0.0465$ between the first two, $z = 2.1$ and $p = 0.0179$ between the second and the third one, and $z = 0.06$ and $p = 0.4761$ between the last two, which shows no significant differences. The results suggest that English might have a strong correlation between the two dimensions, and the preference of associating the future with up and the past with down might be a projection from the sagittal dimension.

In order to reveal the differences between the correlations, another mixed effect logistic regression model was tested. The purpose of the model was to see if a speaker pointed forward for a word, how likely it was that the speaker would point upward for the same word. The model was tested on speakers across the sagittal and vertical dimensions. This model was only tested on the words that were not time related words.

Table 3.21: The results of the model testing the effect of sagittal responses on vertical responses, b: bilinguals, m: monolinguals, responses: front vs. back.

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-0.9542	0.3051	-3.127	<0.01	**
response=front	2.5537	0.24	10.642	<0.001	***
language=English-m	-1.0838	0.3806	-2.848	<0.001	***
language=Mandarin-b	0.6971	0.224	3.112	<0.001	***
language=Mandarin-m	0.7787	0.3268	2.383	<0.001	***
response=front:language=English-m	1.4031	0.3772	3.719	<0.001	***
response=front:language=Mandarin-b	-1.2613	0.3028	-4.165	<0.001	***
response=front:language=Mandarin-m	-1.2816	0.3059	-4.19	<0.001	***

Figure 3.13: Plot for the results of the model testing the effect of sagittal responses on vertical responses, b/dashed line: bilinguals, m/solid line: monolinguals.



The model had speaker and word as random effects, and the interaction between the participants' response in front-back only condition and language condition as a fixed effect, and the dependent variable was the participants'

responses in the up-down only condition. The results are in Table 3.21. It shows that pointing front had a significant effect on pointing up. When a word was pointed as front, the English condition would significantly increase the likelihood of pointing it as up for both the English monolinguals and the bilinguals in the English condition. The results are also shown in Figure 3.13.

The correlations indicate that for the English monolinguals, those who pointed up were also likely to point front, and vice versa. The bilinguals also had the same tendency when the conditions were in English, but only weaker than the English monolinguals, and their tendency to do so when the conditions were in Mandarin and the Mandarin monolinguals' tendency were the weakest.

3.4 Discussion

Results from the restricted conditions show similar results to the any-direction condition. In order to make it visually clear, results from all the conditions are summarized together in Table 3.22.

Speaking overall, all the groups of the participants chose the sagittal dimension as the primary dimension to point for temporal words when they could point freely. Such a result is consistent with the fact that English speakers use the sagittal dimension to gesture time when producing elicited gestures (Casasanto & Jasmin, 2012), and Mandarin speakers use the sagittal dimension to talk about time more often than the vertical one (Chen, 2007).

On the sagittal dimension, the English monolinguals showed consistent patterns between the any-direction condition and the restricted condition. They pointed front for the future more often than for the past, which is consistent with the Moving Ego model in English (Boroditsky, 2000). The bilinguals in the English context behaved like the English monolinguals, and they showed consistent patterns between the two conditions. The bilinguals in the Mandarin context pointed front for the future more often than for the past when there were no overt sagittal cues; however, they pointed front less often for the future and pointed back less often for the past when there were cues. Although sagittal cues had an effect on them, it was not strong enough

to change their associations between time and directions.

Table 3.22: A summary of the results collected from all the conditions across language groups. Grey colour: the results that are inconsistent with the hypotheses, n/p: no preferences, n/a: not applicable.

Group	Dimension	Result-any direction condition		Result-restricted conditions	
English monolinguals	sagittal	Front for the future more often than for the past		Front for the future more often than for the past	
	vertical	Up for the future more often than for the past		Up for the future more often than for the past	
	transverse	Right for the future more often than for the past		Right for the future more often than for the past	
Bilinguals in English	sagittal	Front for the future more often than for the past		Front for the future more often than for the past	
	vertical	Up for the future more often than for the past		Up for the future more often than for the past	
	transverse	Right for the future more often than for the past		Right for the future more often than for the past	
		Having Cues	No Cues	Having Cues	No Cues
Bilinguals in Mandarin	sagittal	Front for the future more often than for the past	Front for the future more often than for the past	Front for the future more often than for the past	Front for the future more often than for the past
	vertical	Up for the past more often than for the future	Up for the future more often than for the past	Up for the past more often than for the future	Up for the future more often than for the past
	transverse	n/a	Right for the future more often than for the past	n/a	Right for the future more often than for the past
Mandarin monolinguals	sagittal	Back for the future more often than for the past	n/p	Back for the future more often than for the past	Front for the future more often than for the past
	vertical	Up for the past more often than for the future	n/p	Up for the past more often than for the future	Up for the future more often than for the past
	transverse	n/a	n/p	n/a	Right for the future more often than for the past

The Mandarin monolinguals showed no preferences when there were no overt sagittal cues in the any-direction condition, and they pointed front less often for the future and pointed back less often for the past when there were

sagittal cues. The Mandarin monolinguals behaved like the bilinguals in the Mandarin condition in the sagittal-only condition when there were cues; however, the effect of the cues was stronger for them than for the bilinguals. The Mandarin monolinguals showed no preference on the sagittal dimension in the any-direction condition when there were no cues. It seemed temporal direction on the sagittal dimension was salient for them only when sagittal cues existed. However, the effect of sagittal cues was consistent across the two conditions for them. The immediate effect of sagittal cues in Mandarin is consistent with Chui's (2011) observation, in which it was found that the Mandarin speakers pointed a past word with a sagittal cue and a past word without it in different directions. The two different temporal directions from the Mandarin speakers show that both the Moving Ego and Moving Time models exist in Mandarin. Yu (2012) suggests that the temporal direction of the Moving Time model in Mandarin is consistent with the direction that is described by Mandarin overt sagittal cues, which are front-past and back-future.

On the vertical dimension, the English monolinguals and the bilinguals in the English condition behaved in similar ways. Both groups also showed similar patterns between conditions. They all pointed up for the future more often than for the past. This result is consistent with the vertical temporal direction in English according to CMT (Lakoff & Johnson, 1980/2003) but not with the predictions, and this result is inconsistent with the existing studies that tested if English speakers had preferred mental timelines (e.g., Boroditsky et al., 2011; Miles et al., 2011). The bilinguals in the Mandarin condition also showed a similar pattern when there were no overt vertical cues. However, they pointed up for the past more often than for the future when there were cues. For the Mandarin monolinguals, the effect of vertical cues is consistent in both conditions. However, when there were no vertical cues, they had no preference in the any-direction condition and they pointed up for the future more often than for the past in the vertical-only condition. The future-up and past-down mappings are not supported by Mandarin linguistic data, and it was never found from English speakers. The future-up and past-down mappings found from the current study might be caused by the experimental design. In almost each pair of the fillers, there were a

word with a positive meaning and a word with a negative meaning. The participants might associate temporal words with valence. The other reason is that there might be a link between the sagittal and vertical dimensions, which is revealed from the correlation test. It was found that when looking at the fillers, the participants' sagittal responses can predict their vertical responses. Correlation tests also reveal that there might be a close connection between the two dimensions. It seems the Mandarin speakers' future-up and past-down associations might be a projection from their future-front and past-back associations on the sagittal dimension. The current unpredicted upward vertical direction remains unexplained and both possibilities requires further tests in future studies.

On the transverse dimension, almost all the participants associated left with the past and right with the future, which is consistent with the writing direction in both Mandarin and English, given the fact that most of the Mandarin speakers in the current study are from mainland China. Only Mandarin monolinguals showed no preference in the any-direction condition.

We can see that the English monolinguals and the bilinguals in the English condition showed similar patterns on the three dimensions. Both groups associated the future with front, up and right, and associated the past with back, down and left. However, the associations for the English monolinguals were stronger than those for the bilinguals in the English condition. The results of the models that tested the combined data of the two groups on the three dimensions also revealed that the two groups behaved significantly differently or tended to have different behaviours. For the bilinguals, language context had significant effects on them in the restricted conditions, which means that overall, time type had the same effect on them in the two different language contexts. However, the difference was that Mandarin cues significantly interacted with time type, whereas preliminary tests showed that English sagittal cues did not interact with time type in English.

The bilinguals in the Mandarin context also behaved differently from the Mandarin monolinguals on the three dimensions. In terms of the effect of spatial cues, both groups were affected by Mandarin spatial cues: they more often pointed to the direction suggested by the cues. However, the effect of spatial cues was stronger for the monolinguals than for the bilinguals in

the Mandarin context. The Mandarin monolinguals showed no preference in the any-direction condition when the words contained no spatial cues, however, they were affected by sagittal cues and vertical cues. One possible reason might be that it was caused by their demographics. As mentioned, their educational levels are presumably high school and technological college, whereas the English monolinguals and the bilinguals were university students. It means that it might take longer for the Mandarin monolinguals to make sense of the experiment. Therefore, they might use the first condition, which was the any-direction condition, to work out what to do in the experiment.

Overall, we can see that, although people in different groups/conditions mostly showed significant different behaviours, the bilinguals in the English condition showed similar associations between time and space to the English monolinguals, and spatial cues had similar effects on the bilinguals in the Mandarin condition and the Mandarin monolinguals. More importantly, the bilinguals mostly behaved differently in the different language contexts.

The current experiment used a pointing paradigm that elicited temporal gestures from the participants and their responses on each dimension were mostly consistent with the temporal direction in the corresponding language. All these suggest that the pointing paradigm was logical when the participants were asked to give deictic gestures for temporal expressions even when the deictic gestures were not produced while accompanying speech. Moreover, comparison between the bilinguals with the monolinguals revealed some cross-linguistic influence important for the current study, that is, on the effect of language on conceptual metaphor.

The first experiment tested how English and Mandarin speakers explicitly associated time with space. When giving materials that have the same meanings across the two languages, English speakers and Mandarin speakers showed different patterns that were caused by overt cues. The explicit task can only reveal a potential immediate effect of overt spatial information on temporal perception. An implicit task is needed to test whether overt directional cues can change people's mental temporal direction. Mandarin speakers' different behaviours for different words also suggested that the direction described by Mandarin sagittal cues is different from the direction of the Moving Ego model in English. In order to find out how speakers of

the two languages implicitly associate time with space, another experiment was conducted. The experiment that tested the effect of time type and language on people's subconscious body movements will be discussed in the next chapter.

Chapter IV

Implicit Associations between Temporal Direction and Body Movements

The first experiment was an explicit task and established a baseline and revealed some potential immediate effect of overt spatial cues. However, one issue with explicit tasks is that they ask people's opinions directly and may not reflect real implicit associations. In order to look at the effect of such cues on people's mental representation of time, implicit tasks are needed; since implicit associations are the subconscious preferences not normally affected by conscious decisions.

4.1 Background

The second experiment investigates the effect of temporal information about the past and the future on people's subconscious bodily behaviour, in other words, their implicit associations between time and space. The second experiment was informed by the contemporary language embodiment theory and CMT. As was discussed in Chapter 2, CMT states that certain metaphors, that is abstract concepts, are described by using concrete domains and experience. Whereas, embodied cognition states that people's cognitive processes are deeply grounded in physical experience, such as situated context, and the interaction with the physical environment through action. Existing studies either test movements of the arm (Koch et al., 2011; Sell & Kaschak, 2011; Ulrich et al., 2012) or the whole body (Hartmann & Mast, 2012; Miles, Nind, & Macrae, 2010) and find a compatibility effect on future-front and past-behind mappings. However, the effect of temporal direction on whole body motor responses on a language that has future-back and past-front mappings as the dominant has never been tested, and these mappings have

been observed in the previous pointing experiment in Mandarin.

The abstract concept “time” is described by using spatial information such as that discussed in the previous chapter. Studies also revealed that temporal understanding and spatial meaning share the same cortical metrics (Walsh, 2003), which are also involved in controlling action in reachable space (Sell & Kaschak, 2011). Therefore, I hypothesize that spatial information such as “before” and “after” in Mandarin in temporal expressions could have a physical effect on the human body. For example, people should lean more forward immediately after they hear a temporal word that contains “before”. Since the two languages have different temporal directions that are expressed by their own spatio-temporal metaphors, bilingual speakers might have different body movement patterns when processing temporal information in the two languages.

4.1.1 Body Movements and Perceiving Temporal Information

Body sway is often studied in fields which relate to bodily health, such as posture control in elderly people, the comparison between healthy people and those with certain diseases, and in biomechanics (Amori, Petrarca, Patané, Castelli, & Cappa, 2015; Aoki, Tokita, Kuze, Mizuta, & Ito, 2014; Bottaro, Casadio, Morasso, & Sanguineti, 2005; Nakakubo et al., 2014). It remains uncertain why people sway their bodies during quiet standing. One possibility is that body sway might simply be a side effect of the human body trying to achieve stability (Bottaro et al., 2005).

However, body sway or body posture is no longer only attracting attention from clinicians who are interested in the postural balance of disabled/healthy people. Recent studies have found that apart from the physical factors that affect our body sway, it is possible that body sway can be affected by perceiving and producing temporal information, such as a potential association between body sway and memory retrieval (e.g., Miles, Nind, & Macrae, 2010). Some studies have also found empirical evidence for a close connection between recalling temporal information and body posture. For instance, Dijkstra, Kaschak, and Zwaan (2007) found that different postural directions could help recall different episodic memories. In their studies, Dijkstra and

others found that when asking English speakers to retrieve episodic memories from the past, the participants' responses times were shorter when the body positions during retrieval were consistent with those in the original events than when they were inconsistent. Their study found a direct link between situated physical status and imagination that involved body sway.

Other studies such as Miles, Betka, et al. (2010) and Miles, Nind, and Macrae (2010), found that body movements can reflect a mental time line on both the transverse and the sagittal dimension. Miles, Betka, et al. (2010) found that people who used a mouse to move an earlier event to the left would draw a different trajectory from people who moved an earlier event to the right, in which physical actions were clearly influenced by left-right writing direction in English. Miles, Nind, and Macrae (2010) adopted a between-participants approach and tested English speakers' body posture by attaching a tracking device on the participants' knees. Their study showed that English speakers lean forward when thinking about the future and lean backward when thinking about the past, which was consistent with the temporal direction of the Moving Ego model in English. However, some others tried to replicate the results but failed (Stins et al., 2016). Stins et al. (2016) adopted a within-participants approach and tested the effect of both mental timeline and emotional valence on body posture by including questions about past/future and positive/negative memories. Their study tested the participants' center of pressure but found that neither mental timeline nor emotional valence could affect the participants' body movements, that is, the participants produced indistinguishable movement trajectories between the past and the future, and between positive and negative memories. A later result from Miles, Karpinska, et al. (2010) suggests that spatio-temporal information and body movements can affect each other, and they found that perceived fictitious body motion can affect thinking about the future and the past. They found that people who saw a fictitious picture giving the impression they were moving forward were more likely to report that they would daydream about the future, while a picture making it seem as if they were moving backward would be more likely to make them think about the past.

However, some studies found that not only can perceived fictitious body

motion affect how people think about time, but real body movements could also affect temporal judgment. For example, Hartmann and Mast (2012) found that people were faster to judge a word about the future when being moved forward, which also suggests that body motion is related to perception of temporal information; however, they also found that passive backward motion did not affect judgment on words about the past.

4.1.2 Body Movements and Producing Temporal Information

Hartmann et al. (2012) also found that self-generated numbers are associated with body motion: people were more likely to produce small numbers when moving leftward and downward, and produce big numbers when moving rightward and upward. However, despite a tendency for people to produce large numbers when moving forward and small numbers when moving backward, statistical analyses did not reveal significant results. The latter study certainly reveals the potential effect of body movements on the producing of an abstract concept: that is, “number”. Since the processing of space, time and number share the same cortical metrics (Walsh, 2003) and these metrics are related to action (Buetti & Walsh, 2009), it is reasonable to believe that self-generated temporal information could also affect action within reachable space. However, the relationship between the production of temporal information and body movements has never been tested, which is one aim of the current study, although it has been evidenced that conceptual metaphors play an important role in language production (Sato et al., 2015). The other advantage of testing body movements during language production is that existing studies (Miles, Nind, & Macrae, 2010; Stins et al., 2016) only asked the participants to think about their past lives and future plans without knowing whether the participants really thought about these events, and therefore testing body movements during language production can guarantee that the participants really think about what have been asked. Furthermore, it has been suggested that forward movement is associated with goal achieving (Natanzon & Ferguson, 2012), so therefore people should associate forward movement with the future, no matter what language we speak, given we all move forward to do things. However, if body movements are

affected by the processing of temporal information in a given language, the effect should also be observed from a language that has a different temporal direction from English.

4.1.3 Body Movements and the Moving Ego Model

In terms of the relationship between motor responses within reachable space and perception of temporal information, various behavioural studies also tested and found compatibility effects on future-front and past-back mappings by making participants produce motor responses (Koch et al., 2011; Sell & Kaschak, 2011; Ulrich et al., 2012). For instance, Koch et al. (2011) tested how German speakers used arm movements to associate words with directions, and they found that participants were faster to move their arms forward when they saw words about the future; and they were also faster to move their arms backward when seeing words about the past. Sell and Kaschak (2011) tested English speakers and Ulrich et al. (2012) tested German speakers on how fast they can move their arms when perceiving sentences related to the future and the past. Both studies found that participants were faster to move their arms out to the front of the body when perceiving sentences about the future, and faster to move their arms towards the body from the front when perceiving sentences about the past.

It can be seen that the findings mentioned above involve the influence between perception of abstract information (time) and body movements, including both arm and whole body, in real and perceived fictitious movement. As has been mentioned, if self-generated abstract ideas can be affected by body movements, then the production of temporal information would cause the same effect, and the current study is going to examine such a possibility by testing the two languages that emphasize different temporal directions. Since the study conducted by Miles, Nind, and Macrae (2010) was the first study that looked at the effect of thinking about temporal information on body-sway, the current study is also going to replicate their results: that is, testing how both native English speakers and ME bilinguals produce body-sway when thinking about temporal information about the past and the future. Lastly, it has been found that perception of temporal information

is linked to action, and such a connection also needs to be tested on different languages. Based on the above literature, three major findings will be observed.

4.1.4 Testing Different Tasks

Firstly, based on the study from Miles, Nind, and Macrae (2010) on the effect of thinking about temporal information on body movements, speakers of a language that potentially has a future-back and past-front spatio-temporal connection such as Mandarin might move their bodies in different directions from English speakers when thinking about temporal information, and English speakers would still show a future-front and past-back connection during thinking. The different mappings between English and Mandarin have been observed in the previous pointing experiment that involved using hands. Therefore, the current experiment looks at people's whole body movement patterns during thinking.

Secondly, the different moving directions between English and Mandarin that are caused by opposite temporal directions in the two languages would also be observed when perceiving temporal information such as listening to stories that have temporal information. In other words, the current experiment tests people's perception of temporal information. As has been discussed, the perception of temporal information on body movements has been studied in languages spoken in western cultures such as English (Sell & Kaschak, 2011) and German (Ulrich et al., 2012). Testing a perception task in a language that has future-back and past-front connection would allow us to closely look at how temporal information is perceived across languages.

Thirdly, the different moving directions would also be observed when producing temporal information, which is based on the idea that conceptual metaphor is also important in language production (Sato et al., 2015). Gibbs (2013) found that understanding of conceptual metaphors requires embodied simulation of metaphorical action. If embodied action is important for speech production, simulation of action should also be observed when producing temporal information. Therefore, the current experiment is going to test how people behave in a production task.

As we can see, the current body sway experiment will test different types of tasks, such as perception and production of temporal information. Production of temporal information has been rarely tested and the current study tests body movement patterns accompanying speech. It has been argued that so far studies that have looked at the Moving Ego and Moving Time models used a limit set of stimuli and tasks, and the results they collected were facilitated by the particular designs of the experiments (Walker et al., 2014). This is the other reason for the current study to test participants' body movement patterns in different tasks, since different tasks have different characteristics and by doing so we can have a better understanding of how body movements are affected by the processing of temporal information.

Different tasks have different mechanisms that could potentially affect participants differently. Perceiving linguistic materials during reading and listening to temporal information requires processing language, and therefore, language context might have a strong effect during perception. Whereas body movement patterns during producing speech might be less affected by language contexts since people's co-speech body sway patterns are learned earlier when acquiring their native languages.

The first experiment, which used the pointing paradigm, suggests that overt directional cues have effects on Mandarin speakers. Mandarin speakers were affected by Mandarin cues. Based on this finding, I predict that overt cues might also have an effect in Mandarin in testing body sway, which is an implicit task. Testing body motion is an implicit way of testing potential association between factors. Research has tested the effect of mental time line on body movements and their results revealed subtle behavioral differences, such as different movement trajectories and slightly different movement distances. People's mental time line and processing of temporal information can be revealed in action. Therefore, tracking body movements during cognitive processing can be seen as an implicit task.

In order to replicate the results from the existing study, the current experiment takes parameters from Miles, Nind, and Macrae (2010) and modifies their measurement methods. It used body-tracking devices to record people's upper body position. Based on the findings from the first experiment (the pointing experiment) and existing studies, and given the fact that the effect

of vertical cues has been tested in the literature in implicit tasks such as the study on Mandarin speakers' co-speech gesture on the vertical dimension, this second experiment is designed in order to answer both the first and the fourth research questions that were asked at the end of Chapter 2. The two questions and more specific questions are listed below.

2. If English and Mandarin have different temporal directions on the sagittal dimension, do monolinguals and bilinguals of the two languages have different body sway patterns during the processing of temporal information about the past and the future?
 - (a) Do native English speakers sway their bodies according to the temporal direction in English during the perception and the production of temporal information in English?
 - (b) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in Mandarin during the perception and the production of temporal information in Mandarin?
 - (c) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in English or in Mandarin during the perception and the production of temporal information in English?
4. Could spatial cues in temporal expression affect how Mandarin speakers perceive time?
 - (a) Do Mandarin speakers associate different directions with temporal information that lacks spatial cues than when the temporal information contains the spatial cue front (or back)?
 - (b) If yes, can the presence of spatial cues in temporal expression affect Mandarin speakers' body movement patterns (in body-sway)?

4.2 The First Body Sway Experiment

4.2.1 Hypotheses

Referring to the aims of the current experiment, I hypothesize the following based on the results from the pointing experiment and existing studies. How-

ever, since people's initial position is never known, which will be discussed in the methodology section, and the future and the past will be compared. The current study will compare people's body sway in terms of relative direction across conditions, instead of looking at absolute directions.

Predictions about Mandarin cues are based on the pointing experiment and the studies conducted by Chui (2011) and Lai and Boroditsky (2013), in which they found that Mandarin spatial cues had immediate effects on Mandarin speakers' temporal perception. The former study found that Mandarin speakers point temporal words with and without spatial cues to different directions, and the latter study found that Mandarin speakers produced more sagittal responses after being prompted with sagittal cues, and they produced more vertical responses after being promoted with vertical cues.

The reason for looking at thinking and talking separately is that people might produce different behaviours. If we assume that body sway patterns accompanying speech are like gestures, then body sway accompanying thinking and body sway accompanying talking might be different. McNeill (1992) proposed that gestures produced with speech have fewer language properties: they are meant to complement the meaning; whereas gestures used in the absence of speech have more language properties. However, there has been little evidence on people's temporal perception and body sway during talking. Therefore, when looking at thinking and talking separately, I hypothesise that people will not behave differently between the two phases. The hypotheses are as follows.

- (a) In the thinking and talking phases, and in the story listening task, English monolinguals will sway more forward for the future than for the past, which is based on the Moving Ego model in English (Miles, Nind, & Macrae, 2010).
- (b) In the thinking and talking phases, and in the story listening task, bilinguals in the English condition will behave like English monolinguals: they will sway more forward for the future than for the past, which is based on the Moving Ego model in English.
- (c) Based on the effects of Mandarin sagittal cues in the pointing experiments, bilinguals in the Mandarin condition will sway more forward for

the past than for the future when listening to Mandarin stories with cues. Based on the immediate effects of Mandarin spatial cues found by Lai and Boroditsky (2013), bilinguals in the Mandarin condition will sway more forward right after hearing a Mandarin-past-front cue when listening to the Mandarin story about the past, and they will sway more backward after hearing a Mandarin-future-back cue when listening to the Mandarin story about the future. When answering questions, in both the thinking and talking phases, they will sway more back for the future than for the past for questions that have cues; and they will sway more forward for the future than for the past for questions that do not have cues.

Hypotheses above are listed in Table 4.1.

Table 4.1: Hypotheses of the body sway experiment from Part I, n/a: not applicable.

Group	Task/Phase	Result	
English monolinguals	Listening to fictitious stories	More forward for the future than for the past	
	Thinking and talking about their own lives	More forward for the future than for the past	
Bilinguals in English	Listening to fictitious stories	More forward for the future than for the past	
	Thinking and talking about their own lives	More forward for the future than for the past	
		Having cues	No cues
Bilinguals in Mandarin	Listening to fictitious stories	More forward for the past than for the future	n/a
		More backward for the future when there is a 'back'	n/a
		More forward for the past when there is a 'front'	n/a
	Thinking and talking about their own lives	More forward for the past than for the future	More forward for the future than for the past

4.2.2 Methodology

Participants

Twenty native New Zealand English monolingual speakers and 20 Mandarin-English bilingual speakers were recruited by using public signs around the campus of the University of Canterbury. Their participation was in exchange for shopping vouchers. Mandarin monolinguals were not recruited because the current experiment needed to use a tracking device located in the Human Interfaces Technologies Lab at the University of Canterbury. It is almost impossible to find Mandarin monolinguals who are of the same age as the

other groups of speakers in the region. All the participants were asked what languages they could speak before they came to the experiment. The questionnaire was the same as the one that was used in the pointing experiment (see Appendix). It asked 6 agree/disagree questions. The inclusion criterion was whether their answers to four questions indicated that their Mandarin was stronger than English. People who could speak a Chinese dialect in addition to Mandarin such as Cantonese or Teochew were not included. One Mandarin-English bilingual was excluded from the experiment at the recruiting stage for her knowledge of Teochew. Therefore, there were 21 applicants and 20 bilinguals selected.

Participants were told that the experiment was to study how individuals think and talk about their past and future lives. The experimenter used English when interacting with the participants prior to the experiment.

Materials

The materials were four short stories. Two English stories were played to the English monolinguals, and the same English stories and two Mandarin stories were played to the bilinguals. All four stories had different content; however, the content was connected. The Mandarin story about the past, was about a young man whose name was Jack and how he found a new job and travelled to different cities and eventually helped his friend Harry, who had just come to the city. The Mandarin story about the future was about Harry's life after he came to the city and his plans for the future. The English story about the past was about Harry, who came to the city, found a new job, how he felt about the new environment and how he eventually established a family with Jack's sister. The English story about the future was about Harry's son, Jimmy, his life and his plans for the future. Each of the two Mandarin stories contained ten time-related phrases which had directional cues, and one story was about the past and the other was about the future. The English stories did not have time-related phrases, and one was about the past and the other was about the future. The stories were designed in such a way as to maximize the chances of an effect. This decision was based on the results from the first experiment, in which it was found that Mandarin speakers showed different

temporal directions from English speakers on the sagittal dimension when Mandarin sagittal cues were in the words. The stories were read by native speakers and recorded by using Audacity (Audacity Team, 2016), and each story was ninety seconds long. The four stories, then, were as follows:

1. A Mandarin story about the past that contained Mandarin-past-front cues such as ‘three days ago’, ‘the day before yesterday’ etc.
2. A Mandarin story about the future that contained Mandarin-future-back cues such as ‘the day after tomorrow’, ‘in five days’ time’ etc.
3. An English story that was about the past, but which contained no sagittal cues.
4. An English story that was about the future, but which contained no sagittal cues.

The stories were counterbalanced between the future and the past. For all the participants, the stories were then followed by fourteen questions which were unrelated to the stories. The questions asked what people did in the past and what they would do in the future. Each Mandarin question contained a temporal word that was similar to one in the pointing experiment. Seven temporal words were about the future and seven were about the past. They were all conventional temporal expressions that were selected to cover time units such as day, week, month and year. As has been discussed, temporal expressions in Mandarin heavily rely on overt spatial cues, and there is no non-spatial way of expressing these time units when using Mandarin conventional temporal expressions. As a result, there were five questions that contained the Mandarin-future-back cue, and five questions had the Mandarin-past-front cue. Two questions had the Mandarin-future-down cue, which were *next week* and *next month* and two questions had the Mandarin-past-up cue, which were *last week* and *last month*. Note that there is no non-spatial way to describe these four expressions in Mandarin. They were included in order to make comparison with the words with sagittal cues, and since they were not the focuses of the current study, the vertical cues were not analyzed.

English questions were created by using direct translation from the Mandarin questions. Each English question contained a temporal word which was a translation from its corresponding Mandarin temporal word. As a result, the fourteen English questions had two English-future-back cues and two English-past-front cues. The four English phrases that contained directional cues were *the day **before** yesterday*, *the day **after** tomorrow*, *the year **before** last* and *the year **after** next*. For example, a question that contained one of these words was: “What did you do *the day **before** yesterday*?” However, since English sagittal cues are not the major focus in the current experiment, (they were the side-effect of direct translations) and compared with the questions without cues, there were only few questions containing English cues and they were not enough to conduct reliable statistical tests, therefore, the English cues were not analyzed. The fourteen Mandarin questions were read by a native Mandarin speaker and the English ones were read by a native English speaker. All the questions were recorded prior to the experiment. During the question section, the order of the questions for each participant was randomized. Table 4.2 gives the list of the fourteen questions that were asked after the two stories.

Table 4.2: List of questions asked after listening to the two stories.

Question	Cues in English	Cues in Mandarin	Time type
1. A nice meal that you had with your friends two weeks ago	no cue	front	past
2.A good movie that you watched the year before last	before	front	past
3.Some progress you made two months ago	no cue	front	past
4.What was your life like five years ago?	no cue	front	past
5.What did you do the day before yesterday?	before	front	past
6.Something that made you happy last week	no cue	up	past
7.What were you doing last month?	no cue	up	past
8.An upcoming event in two weeks' time	no cue	back	future
9.A vacation the year after next	after	back	future
10.A happy activity in two months' time	no cue	back	future
11.What will your life be like in five years' time	no cue	back	future
12.What will you be doing the day after tomorrow?	after	back	future
13.What plans do you have for next week?	no cue	down	future
14>Your major focus for next month	no cue	down	future

For the four stories, the Mandarin stories originally were a little shorter than English stories after being recorded; and Audacity was used in order

to make the Mandarin stories longer than their original lengths by slightly slowing down their speech rate. After being lengthened, the manipulated signal sounded lower than its original form. A sample of the manipulated sound was played to two native Mandarin speakers, and both reported that the manipulated signal sounded natural and a bit lower than English. The problem with this solution will be discussed after presenting the results.

Two versions of the information sheet, consent form and research background information form were created in two different languages, which were given at the beginning of the experiment in order to define the language context of the experiment (see Appendix).

Equipment

The experiment was conducted by using a visualization system called VisionSpace at The Human Interface Technology Laboratory New Zealand (HIT Lab NZ). The VisionSpace is a 3D projection system which has three screens. It has a pair of 3D glasses as glasses targets, and four tracking cameras (model: ARTTRACK2, sample rate: 60Hz), all of which are produced by the ART Tracking system[®]. The four cameras are mounted on top of the three screens. Each camera is about 2.2 metres above the ground. The cameras are about 2 metres apart and form a circle looking at the middle of the circle. A program was written for the tracking system on a computer by Dr. Lee Gun at the Hitlab. The glasses targets have infrared reflective spherical markers, so the cameras can track the location of the glasses every 16ms, and then send the glasses' 3D coordinates to the program on the computer. To record a person's head position, all the person needs to do is to stand in the middle of the circle and put on the pair of glasses.

One potential question is that the experiment used a pair of glasses to track people's body posture, thus people's head movements might affect the result. For any future research, this methodology could be improved. To address the issue, a sample of 10% of the video-recording from the experiments was also checked by an independent RA, and it was found that the participants had some head movements, but most of them were consistent with the direction of the body, that is, the head moved forward while the

body was also moving forward and the head moved backward while the body was also moving backward. There still might be small head movements, but forward movements and backward movements will cancel each other out because mean sway distances were used. More importantly, since trajectories were drawn and compared based on linear models, small head movements had no effects on the relationships between trajectories for the future and the past.

Procedure

All participants were given an information sheet and then asked to complete a personal background information form. They were then asked to sign a consent form. The English monolinguals only needed to do the experiment once and the bilingual speakers needed to do it twice: once in each language. The information sheet was given at the beginning of each session, and the consent form and the background information form were only given in the first session. Since the current experiment only used auditory materials, the three screens were turned off. Each participant was then asked to stand on a marked position, which was approximately at the middle of the circle formed by the four cameras. They were asked to face the screen in the middle, and then put on a blindfold before the experimenter put the glasses on them. For the blindfold, it was an approach used by Miles, Nind, and Macrae (2010), which was to encourage vivid imagery and body-sway (Riley, Balasubramaniam, Mitra, & Turvey, 1998). They were told that the pair of the glasses was to filter out any light that the blindfold could not filter completely. The first task was to listen to two stories in the same language. The second task was to answer fourteen personal questions in the same language as the first task. The experiment always followed this order. The story part was tested first because the stories could also help establish the experimental language context. The other reason is that the participants were required to focus on the content of the stories. By making them listen to the stories first, they were given an impression that they needed to remember the content of the stories in order to answer the following questions. The whole process for each participant was video recorded. The bilinguals came back a week later

and did the whole process in the other language. Half of the English monolinguals listened to the future story first. For the bilinguals, half of them listened to the future story first in one language, and half of them listened to the future story first in the other language. Half of the bilinguals did the English session first and half of them did the Mandarin session first in order to counterbalance.

Measurement

The measurement needed to be as simple as possible. Since the question of the body sway experiment was whether different language speakers have different body movement patterns, this meant that the experiment needed to measure people's swaying distances relative to their initial positions. However, one issue was that body swaying distances were usually measured in terms of absolute directions, i.e., leaning forward and leaning backward were clearly separated by the neutral position. The original study conducted by Miles, Nind, and Macrae (2010) attached a tracking device to people's knees, whereas the current body sway experiment used the pair of 3D glasses. When using body tracking devices, data obtained from a device attached to a participant's knee would have less variability than data received from a device attached to the participant's upper body, because one's upper body has more freedom to move. In the existing study, the initial position was removed from the rest of the data in order to make each participant's data consistent. However, when attaching the device to a person's upper body, the inconsistent initial positions would be much bigger than when attaching the device to the person's knee. Besides, a person's neutral standing posture is almost never known. A person might already sway forward/backward when the device was turned on. Therefore, when looking at the results I did not compare their movement trajectories with 0, because 0 might not be a neutral point; instead, I compared the participants' movement trajectory for the future with that for the past in order to give relative comparisons. The advantage of relative measures is that the participants' movement trajectories for the future and those for the past can be compared without considering if their trajectories are below or above 0.

For the story part for the English monolinguals and the bilinguals, all the stories had a similar length: $t = 90\text{s (story length)} + 10\text{s (operating time)}$. For the 10s of operating time, there were approximately 5 seconds between the beginning of the recording and the beginning of the story, and 5 seconds between the end of the story and the end of the recording. Only data from the 90 seconds were analyzed. The 90 seconds for each trial were then divided into 90 parts; therefore, measurements were taken from each second and the measurement for each second was relative to the initial position of the participants. The reason for dividing each trial by second was to look at how individuals swayed their bodies throughout the course of the story, and the time variable was used as a parameter. By doing so, body movement trajectory can be calculated by using linear regression models. However, times variable in milliseconds from the original reading were still used as a function of when the cues were presented when analyzing the immediate effect of overt sagittal cues in the Mandarin stories.

For the questions stage, since each participant's answer was different in length for each question, each recorded answer was firstly divided into two parts: a thinking phase and a talking phase, to allow for the possibility that people would have different behaviours when they thought and talked. Previous studies on the effect of a mental time line on body movements (e.g., Miles, Nind, & Macrae, 2010) only tested people when they thought about the past and the future. In the current experiment, the thinking phase was analyzed, which was to replicate the results from existing studies, and see if the same result can be found when people talked. Different lengths of talking and thinking had different numbers of observations taken at a consistent lengths of intervals across speakers. Then for each phase, times recorded for each observation were divided by the length of the answer; therefore, different lengths were converted into percentages, which was in order to look at how people swayed their bodies at each observation relative to the length of each talking and thinking phase.

Mean values of movements were then derived for each second of each story for the story stage and for each time point of thinking phases and talking phases for the question stage.

Results of the experiment will be presented in the next section of the

chapter. Results of the production phase will be presented before the perception phase, although the perception experiment was tested first. This is because there is a second perception experiment that needs to be presented afterwards.

4.2.3 Results

4.2.3.1 The Production Task: moving while thinking, and talking

For each question, the participants talked about their answers briefly and gave some details. When a participant paused for more than two seconds, it would usually not be a mid-thought hesitation, but rather that he/she started to give a second part to the answer, thus, being silent for more than two seconds was defined as “thinking”. This decision is based on the distribution of pause durations in speech (Goldman-Eisler, 1961), in which it was found that 99% of pauses during discussions by academic adults are less than two seconds. Thinking phases and talking phases were analyzed separately.

Output data from the tracking system contained 3D coordinates. Coordinates on the Z axis represent the participants' body sway distances. Since each participant stood at a different position and the machine also recorded the standing position throughout the experiment, the initial position for each participant was subtracted from the rest of his/her data; thus, by doing so everybody's initial position was corrected. Negative and positive values represent swaying forward and backward respectively relative to the initial position for that answer.

Model Fitting Strategy for the production section

Linear regression models were tested by using R (R Development Core Team, 2015), with the package Lme4 (Bates et al., 2015) and Language R (Baayen, 2013). Since the default setting for Lme4 no longer calculates p-values because they are unreliable in unbalanced designs (Bates et al., 2015), whether t-values are greater than 2 or smaller than -2 became the criteria for deciding whether an effect was significant. For the bilinguals in the Mandarin condition, a mixed effect linear regression model that contained a three-way

interaction was first conducted. The three-way interaction was between time type (past vs. future), overt sagittal cues (cues vs. no cues), and the time variable (tracking how far through the item response the measurement comes from). It was found that the three-way interaction was significant. Since the production section was conducted after the perception section, the order of the two stories that were tested in the perception experiment was also included in the model. However, the order of the two stories was not found to be significantly affecting the production section. For the English monolinguals and the bilinguals in the English condition, the interaction between time type and time variable was tested for each group. For each model, I also tested the effect of changing the time variable into a restricted cubic spline function (RCS) (Harrell, 2015) of the time variable, since the latter is non-linear and it may be more informative, and conducted an ANOVA test between the two models in order to see whether the results of the ANOVA test were significant. If interactions that had the RCS function were significant, then models with the RCS function would be final models regardless of the original one. When the original interactions were significant and ones with the RCS function were not, final models would depend on the result of the ANOVA test: former ones would be final models when the ANOVA tests were not significant, and ones with RCS would be final ones when the ANOVA tests showed significant results.

When presenting results from the production section, I will present the English monolinguals first, followed by the bilinguals in the English condition and then the bilinguals in the Mandarin condition. For each language group/language condition, results for the thinking phase will be presented first then followed by results for the talking phase. For the perception experiment, I will present the English monolinguals first, followed by the bilinguals in the English condition and then the bilinguals in the Mandarin condition.

English Monolinguals' Thinking Phases

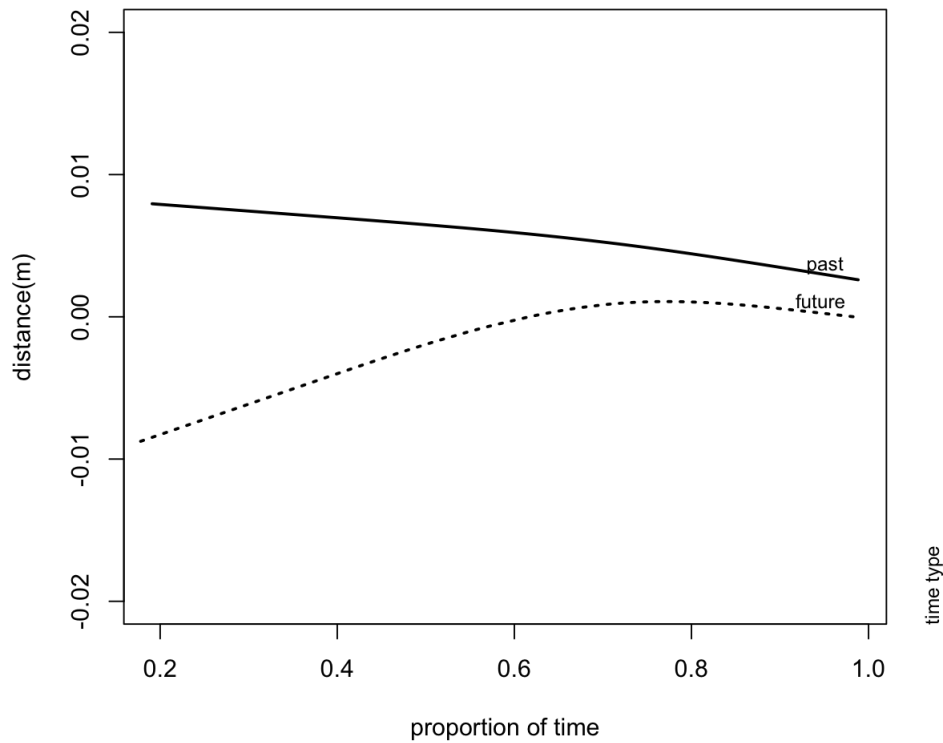
Linear models were tested on the English monolinguals' data. Results of the model are given in Table 4.3. Results of the model show a significant interaction between time variable and time type (t value > 2). The interac-

tion in the model can be better understood when plotted. The model has a significant two-way interaction between time type, and time variable. The significant interaction is plotted in Figure 4.1.

Table 4.3: The results of the model testing the English monolinguals' body sway distances during thinking phases, time: percentage of time length, time type:future vs. past.

	Estimate	Std. Error	t value	
(Intercept)	-0.01256	0.003115	-4.034	***
rsc(time,3)=time	0.02142	0.001294	16.551	***
rsc(time,3)=time'	-0.01565	0.001397	-11.203	***
time type=past	0.02141	0.003272	6.544	***
rsc(time,3)=time:time type=past	-0.02613	0.001575	-16.586	***
rsc(time,3)=time':time type=past	0.01278	0.001778	7.185	***

Figure 4.1: Plots for the results of the model testing the English monolinguals' body swaying distances during thinking phases. Dashed lines: future, solid lines: past.



Note that negative numbers (metres) on the y-axis indicate more forward whereas positive numbers mean more backward. Since the current experiment looks at relative directions instead of absolute directions, attention should be paid to the relationship between the future and the past. For example, in Figure 4.1, the solid line is above the dashed line, which means that the English monolinguals swayed more forward for the questions about the future than those about the past. Numbers on the x-axis represent proportions of time.

English Monolinguals' Talking Phases

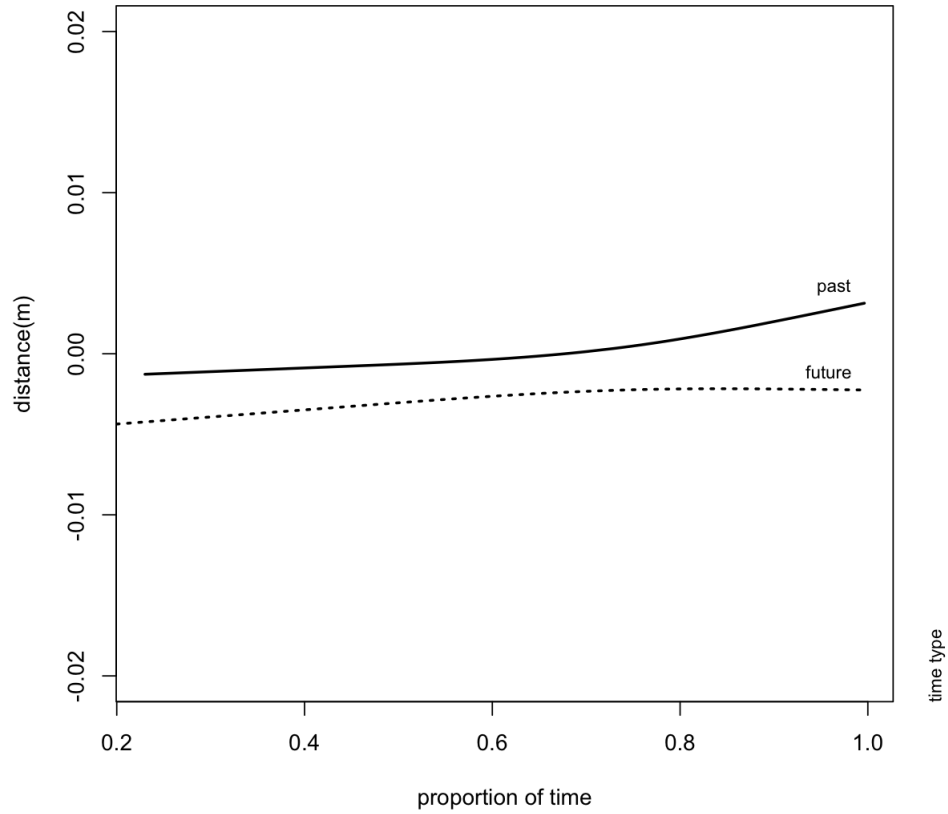
Table 4.4: The results of the model testing the English monolinguals' body sway distances during talking phases, time: percentage of time length, time type:future vs. past.

	Estimate	Std. Error	t value	
(Intercept)	-0.005246	0.003733	-1.405	
rsc(time,3)=time	0.004406	0.000968	4.552	***
rsc(time,3)=time'	-0.002779	0.001135	-2.449	*
time type=past	0.003444	0.004422	0.779	
rsc(time,3)=time:time type=past	-0.002105	0.001325	-1.589	
rsc(time,3)=time':time type=past	0.008062	0.001558	5.173	***

The model that tested the English monolinguals' talking phases also revealed a significant interaction between time type and time variable. The complex results in Table 4.4 are easier to interpret when they are plotted. Figure 4.2 shows that the English monolinguals swayed more forward for questions about the future than those about the past (dashed line below solid line).

When comparing the English monolinguals' thinking phases with talking phases, it was found that they were consistent. The English monolinguals swayed more forward for the future than for the past during both the thinking and talking phases.

Figure 4.2: Plots for the results of the model testing the English monolinguals' body swaying distances during talking phases. Dashed lines: future, solid lines: past.



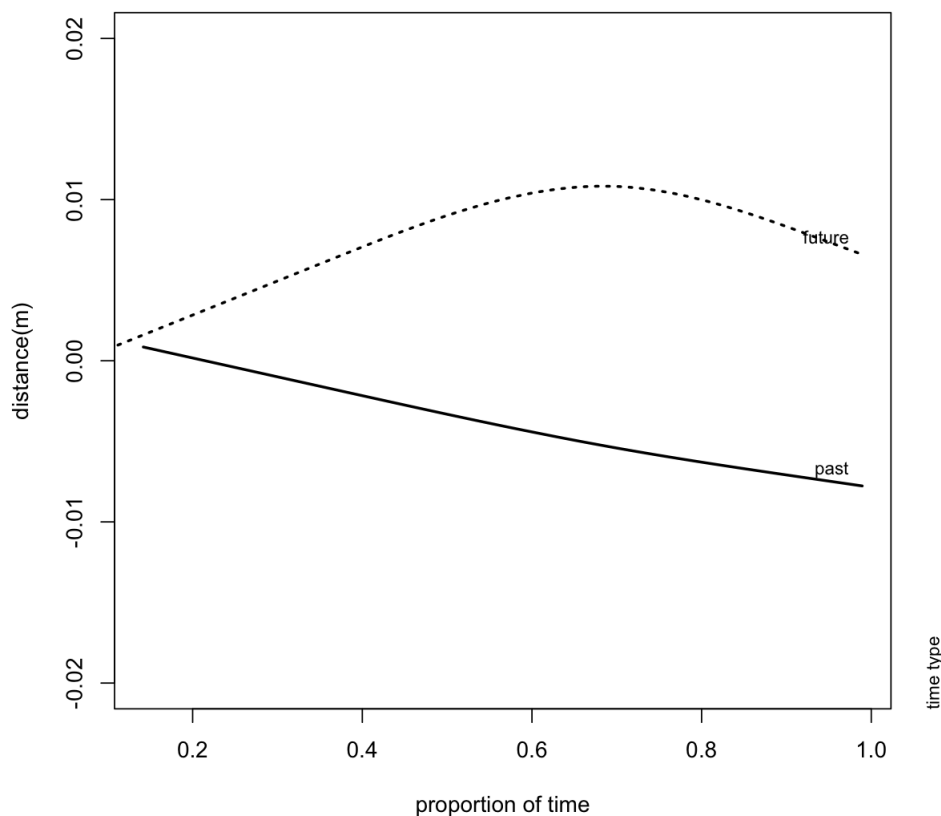
Bilinguals' Thinking Phases in the English Context

Table 4.5: The results of the model testing the bilinguals' body sway distances in the English context during thinking phases, time: percentage of time length, time type: future vs. past.

	Estimate	Std. Error	t value	
(Intercept)	-0.0013942	0.0039301	-0.355	
rcs(time,3)=time	0.0211487	0.0011303	18.71	***
rcs(time,3)=time'	-0.0234534	0.0013062	-17.955	***
time type=past	0.0039054	0.0008885	4.396	***
rcs(time,3)=time:time type=past	-0.0328452	0.0014815	-22.17	***
rcs(time,3)=time':time type=past	0.0257963	0.0017467	14.769	***

Linear models were tested for the bilinguals' thinking phases in the English context. Results revealed a significant interaction between time type and time variable. These complex results in Table 4.5 are plotted in Figure 4.3. It reveals that during the thinking phase in the English context, the bilinguals swayed more back for the future than for the past (solid line below dashed line).

Figure 4.3: Plot for the results of the model testing the bilinguals' body swaying distances in the English context during thinking phases. Dashed lines: future, solid lines: past.



Bilinguals' Talking Phases in the English Context

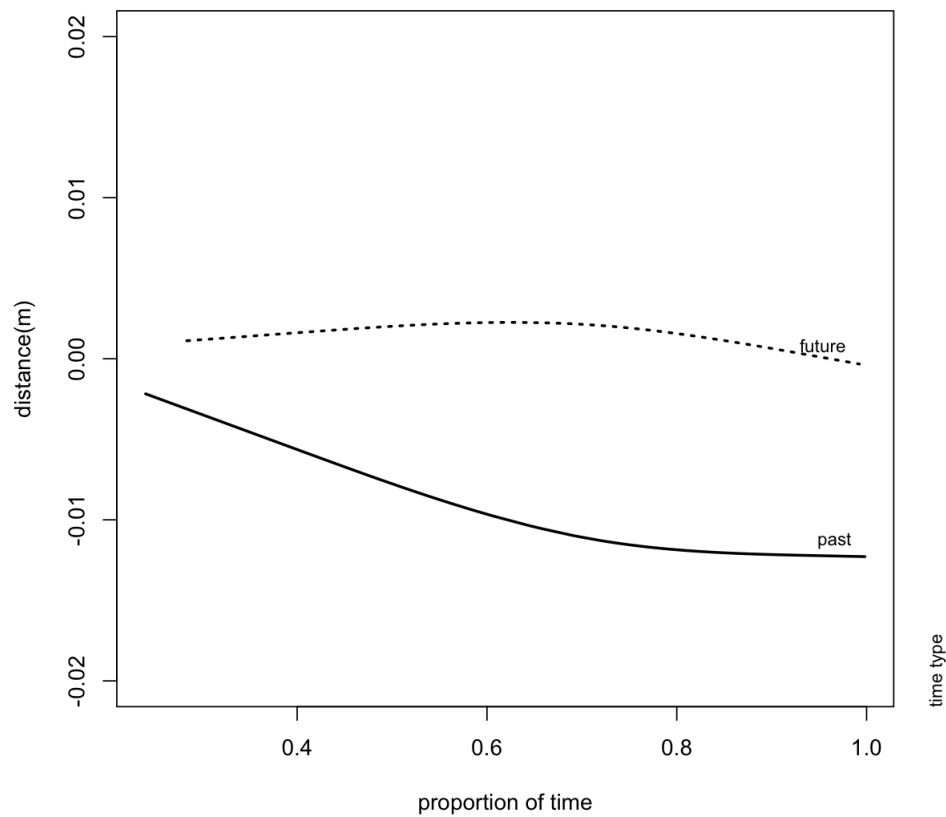
Linear models were tested on the bilinguals' talking phases in the English context. The results are shown in Table 4.6. The interaction is plotted in Figure 4.4. It reveals that during the talking phases in the English context,

the bilinguals swayed more forward for the past than for the future (solid line below dashed line).

Table 4.6: The results of the model testing the bilinguals' body sway distances in the English context during talking phases, time: percentage of time length, time type: future vs. past.

	Estimate	Std. Error	t value	
(Intercept)	-0.0001029	0.0049017	-0.021	
rsc(time,3)=time	0.0042939	0.0010663	4.027	***
rsc(time,3)=time'	-0.0084369	0.0012284	-6.868	***
time type=past	0.0031309	0.0008671	3.611	***
rsc(time,3)=time:time type=past	-0.0259539	0.0013776	-18.839	***
rsc(time,3)=time':time type=past	0.0200804	0.0016096	12.476	***

Figure 4.4: Plot for the results of the model testing the bilinguals' body swaying distances in the English context during talking phases. Dashed lines: future, solid lines: past.



Bilinguals' Thinking Phases in the Mandarin Context

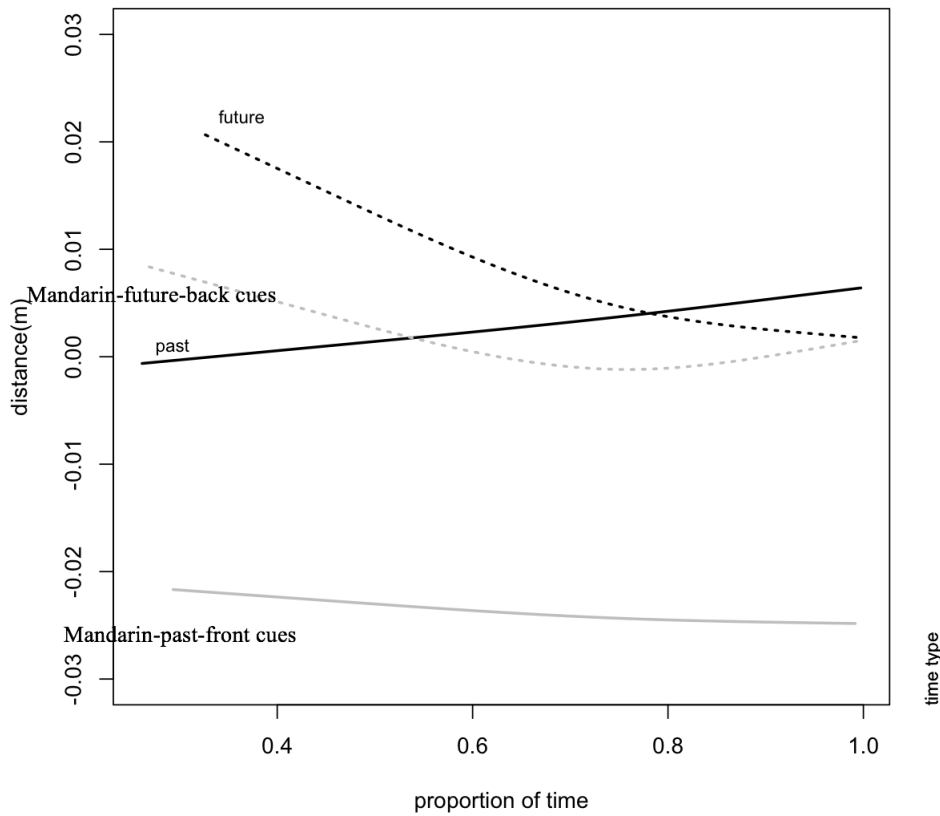
The model for testing the bilinguals' thinking phases in the Mandarin context are shown in Table 4.7.

Table 4.7: The results of the model testing the bilinguals' body sway distances in the Mandarin context during thinking phases, time: percentage of time length, time type: future vs. past.

	Estimate	Std. Error	t value	
(Intercept)	0.034542	0.015723	2.197	*
rsc(time,3)=time	-0.042541	0.00284	-14.977	***
rsc(time,3)=time'	0.019251	0.003356	5.736	***
time type=past	-0.037414	0.022017	-1.699	
cues=yes	-0.019525	0.018693	-1.045	
rsc(time,3)=time:time type=past	0.051126	0.00436	11.728	***
rsc(time,3)=time':time type=past	-0.017829	0.004932	-3.615	***
rsc(time,3)=time:cues=yes	0.017795	0.003442	5.17	***
rsc(time,3)=time':cues=yes	0.003007	0.004023	0.747	
time type=past:cues=yes	0.002634	0.026244	0.1	
rsc(time,3)=time:time type=past:cues=yes	-0.032887	0.005028	-6.541	***
rsc(time,3)=time':time type=past:cues=yes	-0.00161	0.005731	-0.281	

Table 4.7 shows a significant three-way interaction between time type, sagittal directional cues and time variable, which is plotted in Figure 4.5. It reveals that during the thinking phase in the Mandarin context, when the questions had no sagittal cues, the bilinguals swayed more back for questions about the future than for those about the past (black solid line mostly below black dashed line). Similarly, they also swayed more back for the future than for the past (grey solid line below grey dashed line) when there were sagittal cues. In other words, they swayed more forward for the past than for the future regardless of Mandarin sagittal cues.

Figure 4.5: Plot for the results of the model testing the bilinguals' body swaying distances in the Mandarin context during thinking phases. Dashed lines: future, solid lines: past.



Bilinguals' Talking Phases in the Mandarin Context

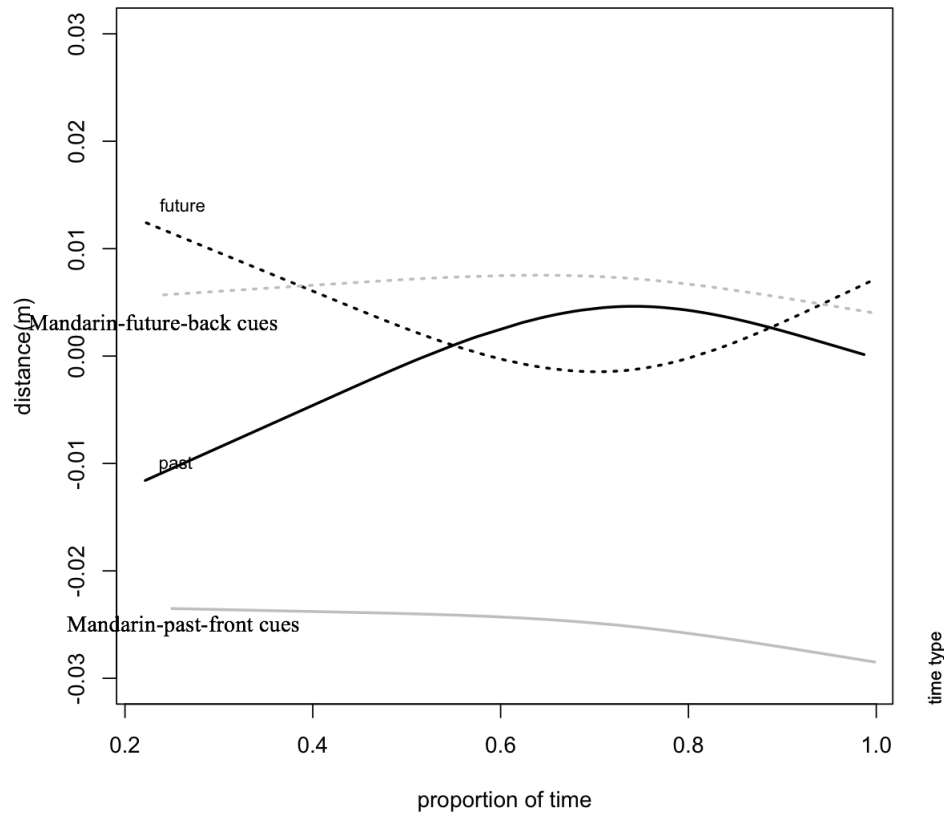
Linear models were tested for the bilinguals' talking phases in the Mandarin context. The results are shown in Table 4.8. Table 4.8 shows a significant three-way interaction between time type, directional cues and time variable, which is plotted in Figure 4.6. It reveals that during the talking phase in the Mandarin context, when the questions have no directional cues, the bilinguals mostly swayed more back for the future than for the past (black solid line mostly below black dashed line). Similarly, the bilinguals also swayed more back for the future than for the past (grey solid line below grey dashed line) when the questions had sagittal cues. We can see that they swayed more back for the future than for the past regardless of Mandarin sagittal cues.

Table 4.8: The results of the model testing the bilinguals' body sway distances in the Mandarin context during talking phases, time: percentage of time length, time type: future vs. past.

	Estimate	Std. Error	t value	
(Intercept)	0.020392	0.017658	1.155	
rsc(time,3)=time	-0.035859	0.002894	-12.391	***
rsc(time,3)=time'	0.04261	0.003007	14.171	***
time type=past	-0.040657	0.024697	-1.646	
cues=yes	-0.016044	0.021005	-0.764	
rsc(time,3)=time:time type=past	0.075047	0.003435	21.85	***
rsc(time,3)=time':time type=past	-0.078526	0.003779	-20.779	***
rsc(time,3)=time:cues=yes	0.041469	0.003234	12.824	***
rsc(time,3)=time':cues=yes	-0.053844	0.003434	-15.678	***
time type=past:cues=yes	0.013265	0.029445	0.451	
rsc(time,3)=time:time type=past:cues=yes	-0.082509	0.003932	-20.981	***
rsc(time,3)=time':time type=past:cues=yes	0.082975	0.004373	18.974	***

When comparing the bilinguals' thinking phases with their talking phases, their results do not show much difference. No matter whether or not there were directional cues in the Mandarin questions, the bilinguals swayed more back for the future than for the past. When making a comparison of the bilinguals' talking phases between the Mandarin context and the English context, their movement patterns do not show much difference. The bilinguals always swayed more back for the future than for the past in both the Mandarin and English contexts.

Figure 4.6: Plot for the results of the model testing the bilinguals' body swaying distances in the Mandarin context during talking phases. Dashed lines: future, solid lines: past.



Summary of the Results

A summary of the results for the question-answering part is given in the table below. Results that were inconsistent with the hypotheses in the corresponding language were marked as X.

Table 4.9 gives a summary of results in the production task. Within each language group or condition, there were no differences between thinking and talking in terms of relative directions between the past and the future. This is consistent with the hypotheses. The bilinguals in the Mandarin condition behaved according to the temporal directions that were suggested by Mandarin sagittal cues, and they still had the same pattern even when the questions had no sagittal cues. The latter result is inconsistent with the hy-

potheses. The bilinguals in the English condition showed opposite moving patterns to those from the English monolinguals, behaving the same way as they did when they were in the Mandarin context, which is also contrary to the prediction and the pointing experiment. Since the current experiment uses implicit tasks, it could be that the default coupling between time and direction on the sagittal axis might be front-past and back-future in Mandarin.

Table 4.9: Summary of the results from moving while thinking and moving while talking. Dark grey: more forward for the future than for the past, light grey: more backward for the future than for the past, x: results that are inconsistent with the hypotheses.

Group	Task/Phase	Result	
English monolinguals	Thinking and talking about their own lives		
ME bilinguals in the English condition	Thinking and talking about their own lives	X	
		Having cues	No cues
ME bilinguals in the Mandarin condition	Thinking and talking about their own lives		X
	More forward for the future than for the past		
	More backward for the future than for the past		
X	Inconsistent with the prediction		

4.2.3.2 The First Perception Task: moving while listening

Model Fitting Strategy for the Perception Section

Several factors were considered to be important. One major factor that was considered to be potentially important was time type, that is, future and past. Since the study needed to look at how people moved their bodies throughout the course of the stories, time variable was also tested. Language was also tested because different groups might behave differently. A preliminary analysis tested the effect of time type, time variable, language group and a potential effect of experimental order. Results of the model revealed complex interaction involving the order of exposure to stories, that is, story numbers were significantly interacting with other factors. It appeared that

participants had different behaviours between the two stories. Therefore, data recorded when listening to the first story were separately analyzed from data recorded during listening to the second story. Since the order of the two stories significantly interacted with other factors, which means that there might be a residual effect from the time type of the first story on the second story, only results from the first story will be reported.

Therefore, for the first story, a model with a three-way interaction between time type, language and time variable was tested. Time type was included because it has more information and could provide us with an overall picture of the effect of time type throughout the course of the stories from different language-speaking groups. For each model, I also tested the three-way interaction and the effect of changing the time variable into a restricted cubic spline function (RCS) of the time variable, since the latter is non-linear and it may be more informative. An ANOVA test between the two models was conducted in order to see whether the results of the ANOVA test were significant. If the three-way interaction with the RCS function was significant, then the model with the RCS function would be the final model regardless of the original one. If the original three-way interaction was significant and the one with the RCS function was not, the final model would depend on the result of the ANOVA test. The former would be the final model when the ANOVA was not significant, and the one with RCS would be the final one when the ANOVA showed significant results.

As has been mentioned, the order of exposure to stories affected the participants in the story listening part. Linear models and ANOVA tests were conducted on data collected from participants' first story listening part. The final model contained time type, language and time variable (without RCS) as a fixed effect and participant as a random intercept. Table 4.10 presents the final model.

The model reveals a significant three-way interaction between time variable, time type and language. In order to make plots clear and visually accessible, different language-speaking groups are plotted separately. Results for the English monolinguals are plotted in Figure 4.7.

Table 4.10: The results of the model testing the participants' body sway distances when they listened to the first stories, time: time variable in seconds, time type: future vs. past, bi-English: bilinguals in English, mono-English: English monolinguals.

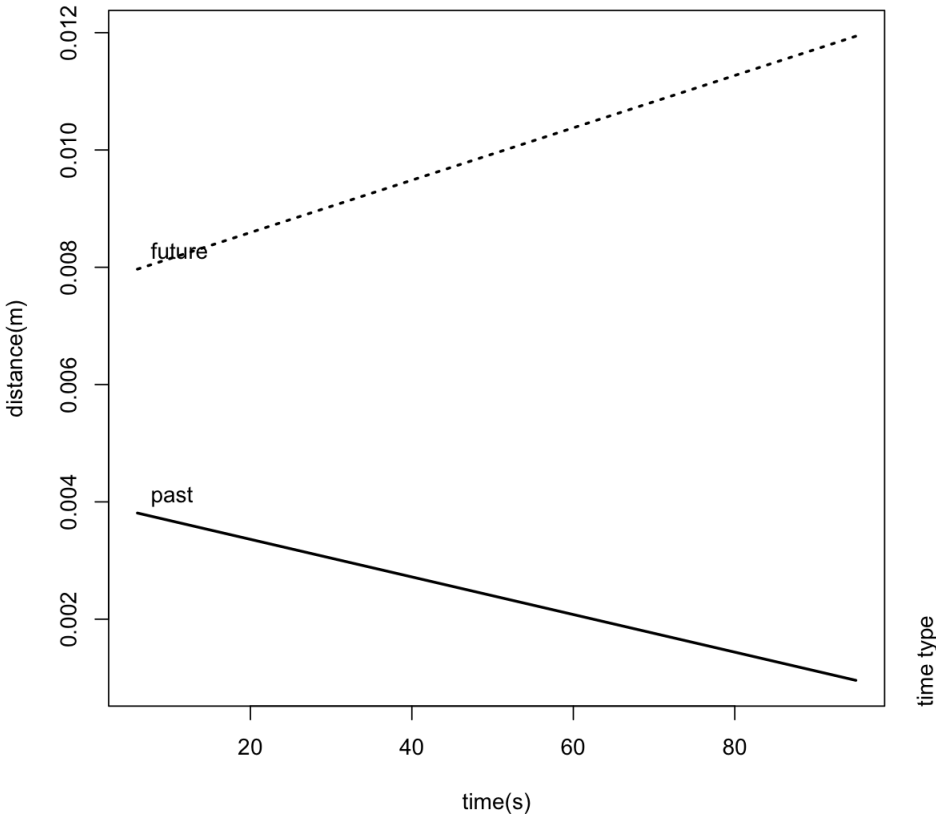
	Estimate	Std. Error	t value	
(Intercept)	0.005429	0.00376	1.444	
time	0.00009001	0.00002272	3.961	***
time type=past	-0.01073	0.001912	-5.609	***
language=bi-english	-0.01273	0.001932	-6.585	***
language=mono-english	0.002272	0.006342	0.358	
time:time type=past	-0.00008164	0.00003064	-2.664	**
time:language=bi-english	-0.0001768	0.00003231	-5.472	***
time:language=mono-english	-0.00004538	0.00003165	-1.434	
time type=past: language=bi-english	0.02929	0.002714	10.792	***
time type=past: language=mono-english	0.007028	0.00747	0.941	
time:time type=past: language=bi-english	0.0001458	0.0000435	3.351	***
time:time type=past: language=mono-english	0.00000495	0.00004346	0.114	

The next three figures are from the model that tests the perception of the first story, and therefore numbers on the x-axis are only for the first story.

English Monolinguals

Note that since the linear model did not contain the RCS function, trajectories in the plot are straight lines. Numbers on the x-axis represent time in seconds and each story is 90 seconds. Numbers on the y-axis represent distance in metres. Figure 4.7 shows that the English monolinguals swayed more forward for the story about the past than for the one about the future. Such a pattern is inconsistent with the hypotheses and the Moving Ego model in English.

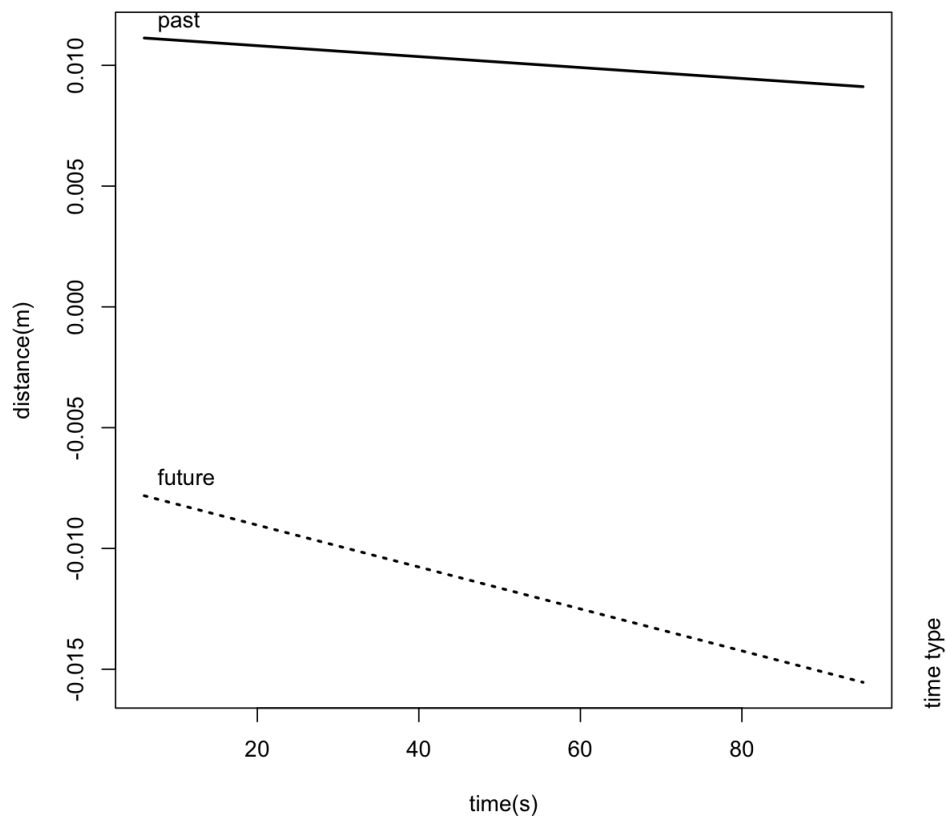
Figure 4.7: The interaction between time variable and time type for the English monolinguals from the model testing the participants' body swaying distances during listening to the first story. Time type: future vs. past, dash line: future, solid line: past.



Bilinguals in the English Context

The bilinguals' data in the English context from the significant three-way interaction were plotted in Figure 4.8. It shows that the bilinguals in the English context swayed more forward for the story about the future than for the one about the past. The pattern is consistent with the prediction and the temporal direction of the Moving Ego model in English on the sagittal dimension.

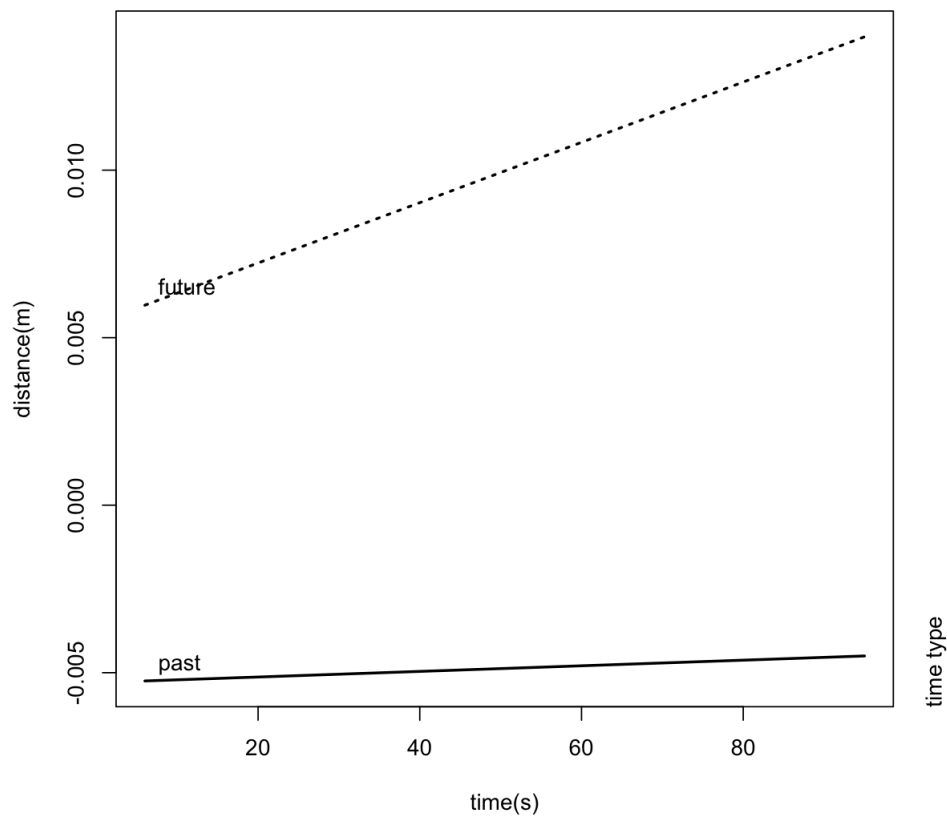
Figure 4.8: The interaction between time variable and time type for the bilinguals in the English context from the model testing the participants' body swaying distances during listening to the first story. Time type: future vs. past, dashed line: future, solid line: past.



Bilinguals in the Mandarin Context

The bilinguals' data in the Mandarin context from the significant three-way interaction were plotted in Figure 4.9. It shows that the bilinguals in the Mandarin context swayed more forward for the story about the past than for the one about the future. In other words, this pattern is consistent with the future-back and past-front temporal direction (the Moving Time model) in Mandarin.

Figure 4.9: The interaction between time variable and time type for the bilinguals in the Mandarin context from the model testing the participants' body swaying distances during listening to the first story. Time type: future vs. past, dashed line: future, solid line: past.



The Immediate Effect of Directional Cues during Listening

The pointing experiment found that directional cues in Mandarin have an immediate effect on people's perceptions of time. In the current perception experiment, the Mandarin story about the past contains ten Mandarin-past-front cue *qian* (front) and the Mandarin story about the future contains ten Mandarin-future-back cue *hou* (back). In order to look at the immediate effect of directional cues, three different periods of time were extracted: a one second window, a two second window and a three second window after hearing each sagittal cue. Linear models were tested and directional cues were found to be not significant or near-significant for the one second windows and

two second windows. Only three seconds windows showed significant results. A comparison between data from this longer window after each cue and the rest of the data was made by running a mixed effect linear model. The model contained participants as a random effect and whether the readings were captured within the three-second window as a fixed effect.

The model shows that the Mandarin-future-back cue has a significant effect on people's body movement directions (estimate 0.0008675, *t* value 8.454). Note that negative values mean swaying more forward and positive values mean swaying more backward. The positive estimated value means that right after hearing the Mandarin-future-back cue, which is *hou* (literal meaning back), the bilinguals swayed more backward than when not hearing the cue, given that they swayed more backward when listening to the Mandarin story about the future. A similar model was also tested on the Mandarin story about the past, and the result shows that the immediate effect of the Mandarin-past-front cue was significant (estimate -0.0004143, *t* value -4.726). The negative estimated value means that right after hearing the Mandarin-past-front cue, which is *qian* (literal meaning front), the bilinguals swayed more forward than when not hearing the cue, given that they swayed more forward when listening to the Mandarin story about the past.

For the English stories, the story about the past used past tense. When telling a story in English, it is always assumed that the story has happened already unless more information about the future is needed. Therefore, when listening to a story about the past, people would activate a 'past' mode and no element can be tested. On the contrary, when telling a story about one's future plans, it is always necessary to remind the listener that things mentioned in the story have not happened yet, by using future markers such as *will* and *going to*, both of which were used in the current experiment for the English story about the future. Therefore, the immediate effect of future markers was tested on both the English monolinguals and the bilinguals in the English condition.

It was found that English future markers had significant effects on the English monolinguals (estimate 0.0003211, *t* value 3.769). The positive estimate value indicates that the English monolinguals swayed more back after hearing the future markers. This pattern matches their overall results: they

swayed more back for the future than for the past. On the contrary, the bilinguals in the English context significantly swayed more forward after hearing the markers (estimate -0.0008922, t value -10.404). This pattern is consistent with their overall patterns: they swayed more forward for the future than for the past in the English context.

Summary of the Results

Analyses from the first story reveal some interesting results. When analyzing the data, preliminary analysis revealed that the order of exposure to the stories significantly interacted with other factors. As a result, only the first story was reported here since the second story was affected by the time type of the first story. Table 4.11 is a summary of the results from the first perception task.

Table 4.11: Summary of the results collected from the first perception task. Dark grey: more forward for the future than for the past, light grey: more backward for the future than for the past, n/a: not applicable, x: results that are inconsistent with the hypotheses.

Group	Task/Phase	Result	
English monolinguals	Listening to fictitious stories	X	
Bilinguals in English	Listening to fictitious stories		
		Having cues	No cues
Bilinguals in Mandarin	Listening to fictitious stories		n/a
	More forward for the future than for the past		
	More backward for the future than for the past		
n/a	Not applicable		
x	Inconsistent with the prediction		

Discussion for the first body sway experiment

As we can see, the English monolinguals did not behave as expected. They swayed more forward for the past than for the future when listening to the

stories. One possibility is that they might activate the Moving Time model after they had been standing for a while. Existing work has found that English speakers who have experience waiting are more likely to activate the Moving Time model (Boroditsky & Ramscar, 2002). It is possible that the English monolinguals activated the Moving Time model after being waiting during the operating time, and in the Moving Time model the past is associated with front.

The bilinguals behaved expectedly according to the Moving Ego model in the English condition, which was consistent with the hypothesis. During listening, they swayed more forward for the future than for the past in the English condition and they swayed more backward for the future than for the past in the Mandarin condition. This result reveals the effect of language on body movement patterns in ME bilinguals.

However, there were some issues. As has been mentioned, the audio files of Mandarin stories were modified in order to make them the same length as the English stories. The speech rate of the Mandarin stories was slightly lower than normal, the overall pitch was lowered, and formant frequencies were changed. It is unknown how the bilinguals felt about modified speech sound. Based on my personal opinions the modified signal sounded normal but seemed to be monotone. I also asked their opinions from two female Mandarin native speakers of the modified signal, and both of them said that the pronunciation of each word was no problem but the person who produced the sound seemed to have a bad personality. Despite the modified sound sounding monotonous, the bilinguals in the Mandarin condition still behaved as predicted, which suggests that the slightly lowered sound had only a minor potential impact, caused by not liking the speaker, for the bilinguals in Mandarin condition. Despite this, this issue was fixed in the second perception task, which will be presented later in the current chapter.

If we look at the size of the participants' movements, we can see that their movements were tiny. Numbers on the y-axis in each figure indicate that the differences between moving forward and moving backward were within centimetres, and sometimes can be within one centimetre. This is in fact consistent with the existing study (Miles, Nind, & Macrae, 2010), which showed that the differences between moving forward and moving backward

were approximately 8 millimeters. It also suggested that the effect of temporal information on body movements was subtle in both the current and existing studies.

Despite the result that bilinguals showed different moving patterns when listening to stories in different languages, separate effects of language and directional cues are still unknown because the English stories had no cues and the Mandarin stories did have cues, thus, whether the effect was from language or from the cues is unknown. In the pointing experiment, participants were told that the experiment was to test how they associate concept with directions, thus participants could consciously choose a direction for each concept, which was an explicit task. However, in the body-sway experiment, participants paid attention to the content of the stories, so language and cues might have played a subtler role in affecting people's body sway than in affecting participants' pointing directions. In order to tease apart the two factors for bilinguals, that is, language and cues, another experiment was designed which had six stories. The next experiment was only tested on ME bilinguals and used the four stories that were used in the first perception experiment, and added two more Mandarin stories that had no sagittal cues. For the Mandarin stories with directional cues, they were included in order to replicate the result for Mandarin bilinguals from the first perception task, in which it was found that the bilinguals swayed more backward for the future than for the past regardless of cues in the Mandarin condition, and they swayed more backward for the past than for the future in the English condition. The next experiment would use a new measurement system that was not affected by the movements of the head, and a new way to capture people's neutral positions. This experiment would also use original sounds as material instead of using modified signals. It was hoped that the next perception task could tease apart the effect of language and sagittal cues, and whether bilinguals would still behave as in the first perception task.

4.3 The Second Body Sway Experiment

4.3.1 Hypotheses

Based on the design of the next experiment, which will be discussed afterwards, I hypothesize the following predictions for the next task.

- (a) During the English context, bilinguals will sway more forward for the future than for the past, which is based on the Moving Ego model in English.
- (b) During the Mandarin context, bilinguals will sway more backward for the future than for the past when listening to Mandarin stories with directional cues, which is based on the results from the pointing experiment.
- (c) Based on the results from the pointing experiment, bilinguals will sway more forward for the future than for the past when listening to Mandarin stories without cues.
- (d) Similarly to the first perception task, in the current experiment Mandarin directional cues will have an immediate effect on the bilinguals, and bilinguals will sway towards the directions that are suggested by the Mandarin cues during a period of time after they hear the cues.

4.3.2 Methodology

Participants

Twenty Mandarin-English bilingual speakers were recruited by using public signs around the campus of University of Canterbury. None of them was in the first perception task, the production task, the pointing experiment or the experiment that will be presented afterwards. Their participation was rewarded with \$20 in shopping vouchers. All the participants were asked what languages they could speak before they came to the experiment. The questionnaire was the same as that used in the previous experiments. It asked six agree/disagree questions. The inclusion criterion depended upon

their answers to at least four questions that indicated their Mandarin was stronger than their English.

The participants were told that the experiment was going to test their body temperature when they listened to different stories. In order to convince them, the experimenter showed them an App which was called the Thermal Camera HD Effect. It looked like a thermometer camera on the phone, but in fact the App can only make the vision of the camera look colourful¹.

Materials

The materials were six short stories: two English stories and four Mandarin stories. The two English stories and two of the four Mandarin stories were identical to the ones in the previous body-sway experiment (the first perception/listening task). The other two Mandarin stories with one about the past and one about the future were added. They had very similar content to the two existing Mandarin stories, but the only crucial difference was that the new ones had no directional cues in them. The six stories were re-recorded by another female native speaker so that all the stories were read by the same voice. The English stories were recorded by a native English speaker. The six stories were as follows:

1. A Mandarin story about the past that contained directional cues such as ‘three days ago’, ‘the day before yesterday’ etc.
2. A Mandarin story about the future that contained directional cues such as ‘the day after tomorrow’, ‘in five days' time’ etc.
3. A Mandarin story about the past that contained no directional cues.
4. A Mandarin story about the future that contained no directional cues.
5. An English story that was about the past, but which contained no directional cues.

¹ The strategy was approved by the Human Ethics Committee. Participants were given a debriefing sheet after the experiment which revealed the true purpose of the study and they were given the opportunity to withdraw at this point if they wished so.

6. An English story that was about the future, but which contained no directional cues.

The purpose of six stories was to make good comparisons, which was the unsolved problem from the previous perception task. If bilinguals sway in different patterns between two English stories without directional cues and two Mandarin stories without directional cues, then the difference may be caused by the languages. Note that there were no English stories with directional cues. However, if bilinguals sway in different directions between two Mandarin stories without directional cues and two Mandarin stories with directional cues, then the difference may be caused by the directional cues.

Another rectification was carried out which was that this time it was necessary to make sure that all the stories had the same length, so the sound did not need to be modified.

Equipment

The Hitlab was unavailable when the second experiment started, thus, it used a different measurement system. The device used by the current experiment was a Samsung cell phone. The phone has a built-in sensor which can sense the effect of gravity on the phone. An App was also installed on the phone which was G-Sensor Pro. G-Sensor Pro can record changes of gravity in a 3D system, that is, changes of gravity on three dimensions between -9.8m/s^2 and 9.8m/s^2 . The x-axis represents the transverse dimension, the y-axis represents the vertical dimension and the z-axis represents the sagittal dimension. When the phone is truly vertically located, readings will be 9.8m/s^2 on the y-axis, 0 on the x-axis and 0 on the z-axis. When the phone is tilted forward or backward, readings on the y-axis will be less than 9.8m/s^2 , and readings on the z-axis will be negative or positive respectively, and readings on the x-axis will be 0. When the phone is tilted leftward or rightward, readings on the x-axis will be positive or negative respectively, readings on the z-axis will be 0 and readings on the y-axis will be less than 9.8m/s^2 .

A wooden board was designed for the purpose of attaching the phone to the participants' upper bodies by the research technician at The New Zealand Institute of Language, Brain and Behaviour (NZILBB). The wooden board

had adjustable straps on it so a person could put it on like a backpack, and the belt on the waist could stabilize the board so it would be tightly attached to the person's upper body. There was also a piece of sponge on one side of the board so when a person put it on it would be comfortable. There was a plastic frame mounted on the top of the board. The size of the frame was adjustable so the cell phone would not loosen when it was placed inside the frame. The wooden board was attached to people's upper bodies instead of people's heads, so there was no need to worry about people's slight movements from their heads.

Procedure

Participants listened to two English stories and four Mandarin stories which were presented in random orders. The current experiment only had one session instead of two, for practical reasons. The current experiment had too many experimental conditions to counter-balance the order of language, directional cues and time type. Such counter-balances would require the recruitment of more participants than the previous experiment. By using random order of the stories, the experiment did not have to counter-balance across conditions and it did not require a larger number of participants.

Participants were given an information sheet and then asked to complete a personal background information sheet. Then they signed a consent form. The order of the stories for each participant was randomly generated in R before the experiment. The language of the information sheet, the personal background information sheet and the consent form was identical to the language of the first story. The language that was used by the experimenter was also the same as the language of the first story they listened to.

After completing all the forms, participants were asked to stand comfortably and face two speakers. Then they put on the wooden board. The experimenter showed them the thermometer App on the phone before putting the phone in the frame, which was in order to convince them that the phone was going to record their body temperature. The participants then put on a blindfold and the experimenter quickly closed the thermometer App and turned on the accelerometer.

After listening to each story, the experimenter turned off the accelerometer and asked the participants to sit down to complete a question sheet. Each question sheet contained four questions about the content of the previous story. The questions served two purposes: as a distraction so the participants would be misled about the true purpose of the experiment and to minimize the effect of the language of the previous story by postponing the beginning of the next story and causing the participants to reposition themselves physically. Each participant spent around one minute answering each question sheet.

Figure 4.10: A snapshot from one participant's captured video.²



There was an introduction before each story, which told the participants what to do. The language of the introduction was same as the language of its following story, and the introduction was about half a minute long. After listening to each introduction, the accelerometer was turned on and the experimenter waited for 15 seconds as operating time before starting to play the story. With the question sheets, the introduction and the operating

² This participant agreed to have his photos published when signing the consent form.

time, it was hoped that the effect of the previous story on the next one would be minimized. In fact, the gap between stories was longer than it was in the previous perception task. The whole process for each participant was video recorded. Figure 4.10 shows a snapshot from a captured video for one participant.

Measurement

Each participant's acceleration was recorded in each story. For the data from each story, there were 15 seconds of operating time before the beginning of the story. The 15 seconds of operating time served two purposes: to help create the language context for the following story and to measure people's neutral positions. Since participants' heights were unknown, it was impossible to convert unit of acceleration into unit of length. For each story for the participants, the mean value of acceleration from the 15 seconds was subtracted from the rest of the data. Without knowing the participants' physical condition, it was assumed that the 15 seconds would be at least close to one's neutral body posture and could better capture a person's neutral standing posture rather than a single data at the beginning of the story, since people might be swaying at the beginning. After that, mixed effect linear models were conducted on the data.

Model Fitting Strategies

For practical reasons, the experiment used randomized orders for the six stories; otherwise it would be hard to counter balance. The consequence of randomized order was that the previous language context for each story was variable across participants. As has been mentioned, the time type (future vs. past) of the first story was tested in linear models in the previous perception and production tasks, and it was found that it had significant effects in the perception experiment but not in the production experiment. There was no need to worry about the language of the first story in both experiments because all the materials in one condition/context would be in the same language.

However, this was not the case in the current experiment. Both the time

type and the language of the first story needed to be tested as potential factors. Although some strategies were used to minimize the effects of previous stories, for example, the same language introduction at the beginning of each story and answering question sheet at the end of each story, it was suspected that the very first story might establish an overall language context in addition to the language of the current story affecting the participants. This was because the language of the first story was the language of the information sheet, consent form and initial interaction, which helped defined the whole context. Therefore, the language of the first story and the time type used in the first story were also included as a potential factor in the models. Other potential factors were the time type of the current story, that is future versus past, language, participants, values on y axis and the position of the story.

One thing that needs to be mentioned is the effect of changes on the y-axis on changes on the z-axis. Values on the y-axis are also included to control for the possibility that values on the z and y-axes might influence each other, and that vertical movements may introduce unwanted variation on the z axis. The phone used in the experiment was never truly vertical when being tested. As a result, when the phone was tilted, moving vertically would also cause the value to change on the z-axis. For example, when a participant changed his posture on the upper body such as squaring his chest, values on the z-axis would also change. The question is whether changes of values on the z-axis were caused by participants' moving vertically rather than the body swaying forward and backward. To address this issue, the correlation was tested between data on the y-axis and z-axis, and the result was -0.1733961, which revealed a weak correlation. Standard deviations were also calculated on the y-axis and z-axis, and the results were 0.1423541 and 0.3524313 respectively, which means that values on the two axes were distributed differently. It seems very unlikely that the recorded movements on the z-axis were an artifact of movements on the y-axis, as the deviation on the z-axis was much greater. However, the y-axis movements were included in all the models, in order to control for this possibility. Furthermore, since the experiment used a device that was attached to people's upper bodies instead of their heads, there was no need to worry about head movements.

Since directional cues were only tested in Mandarin when comparing sto-

ries with cues to stories without cues, directional cues were tested in the subset of the data. For the overall model, three-way interactions were tested. ANOVA tests were conducted when adding the RCS function of time variable into the model. The priority of the model was to test the effect of time type and language.

4.3.3 Results

4.3.3.1 The Second Perception Task: moving while listening

Effect of Directional Cues in Mandarin

As has been mentioned, adding two new stories was to make a good comparison between Mandarin stories with directional cues and Mandarin stories without cues so that the effect of overt sagittal cues could be tested. In order to capture the effect of directional cues, a mixed effect linear model was tested on the four Mandarin stories only. The language and time type of the very first story were tested, which has been discussed in the previous methodology section. Since four factors were needed to be tested: language of the first story, time type of the first story, directional cues and time variable, a four-way interaction was first tested and the results revealed that the interaction was significant.

However, a four-way interaction is hard to interpret. Therefore, data from the Mandarin stories were divided into two subsets according to languages of the first story. Mandarin stories that had an English story as the first story and Mandarin stories that had a Mandarin story as the first story were tested separately. For each subset, the model has participants as a random effect, values on y axis, and the interaction between time type of the first story, directional cues and time variable as fixed effects. The model that tested Mandarin stories when the first story was in English is given in Table 4.12, and the model that tested Mandarin stories when the first story was in Mandarin is given in Table 4.13.

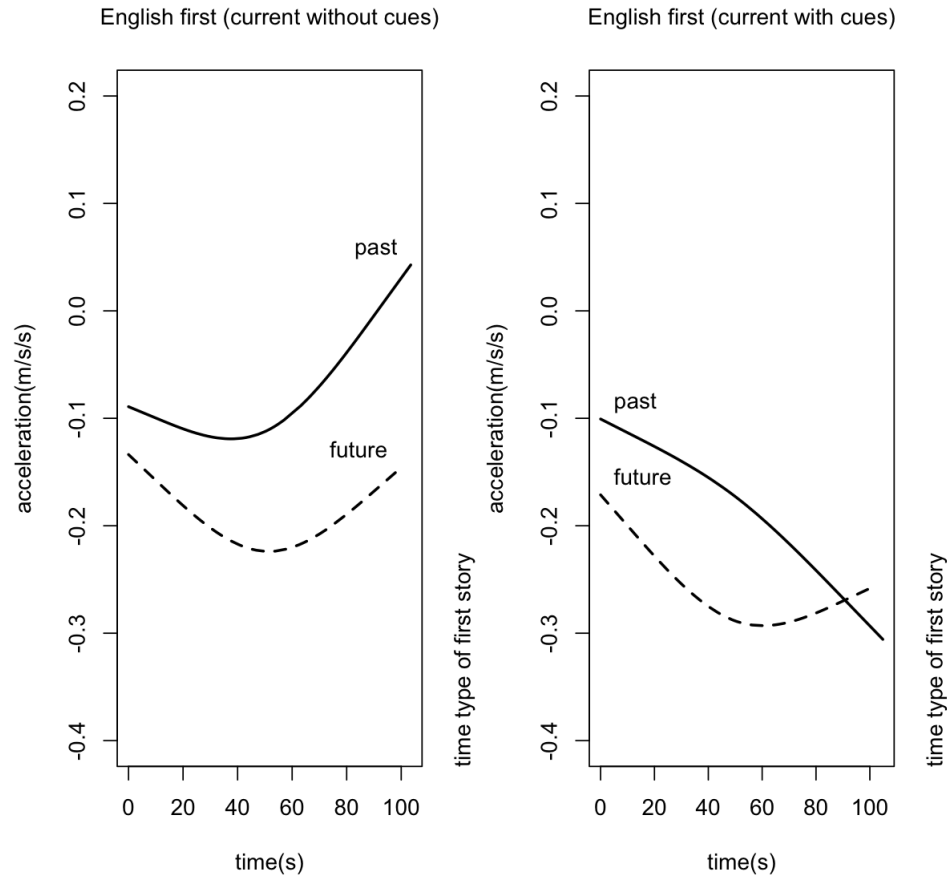
Table 4.12: The results of the model testing the effect of directional cues on Mandarin stories when the first story was in English, first time type: future vs. past, cues: yes vs. no, time: time variable, Y values: values on the vertical dimension.

	Estimate	Std. Error	t value	
(Intercept)	-0.217	0.06934	-3.13	*
Y value	0.6239	0.01154	54.08	***
position	0.05697	0.001368	41.65	***
rsc(time,3)=time	-0.002418	0.0002589	-9.34	***
rsc(time,3)=time'	0.003128	0.0003316	9.44	***
cues=yes	-0.01735	0.01092	-1.59	
first time type=past	0.05476	0.1199	0.46	
rsc(time,3)=time:cues=yes	-0.0005191	0.0003593	-1.44	
rsc(time,3)=time':cues=yes	-0.0002857	0.0004462	-0.64	
rsc(time,3)=time:first time type=past	0.001292	0.0004484	2.88	**
rsc(time,3)=time':first time type=past	0.00005569	0.0005743	0.1	
cues=yes:first time type=past	-0.02476	0.01929	-1.28	
rsc(time,3)=time:cues=yes:first time type=past	0.0003924	0.0006223	0.63	
rsc(time,3)=time':cues=yes:first time type=past	-0.003822	0.000773	-4.94	***

Each model reveals a significant three-way interaction between time type of the first story, directional cues and time variable. Values on the y-axis was also significant. The complex interactions for the two models are plotted in Figure 4.11 and Figure 4.12. Within each figure, the interaction is plotted into two plots based on the existence of Mandarin cues.

Figure 4.11 shows that when listening to the Mandarin stories that had an English story as the first story, the participants swayed more forward when the first story was about the future than when the first story was about the past, no matter whether the Mandarin stories had cues or not (dashed lines below solid lines).

Figure 4.11: Plots for the results of the models testing the effect of directional cues on Mandarin stories when the first story was in English. Dashed lines: when the first story was about the future, solid lines: when the first story was about the past.



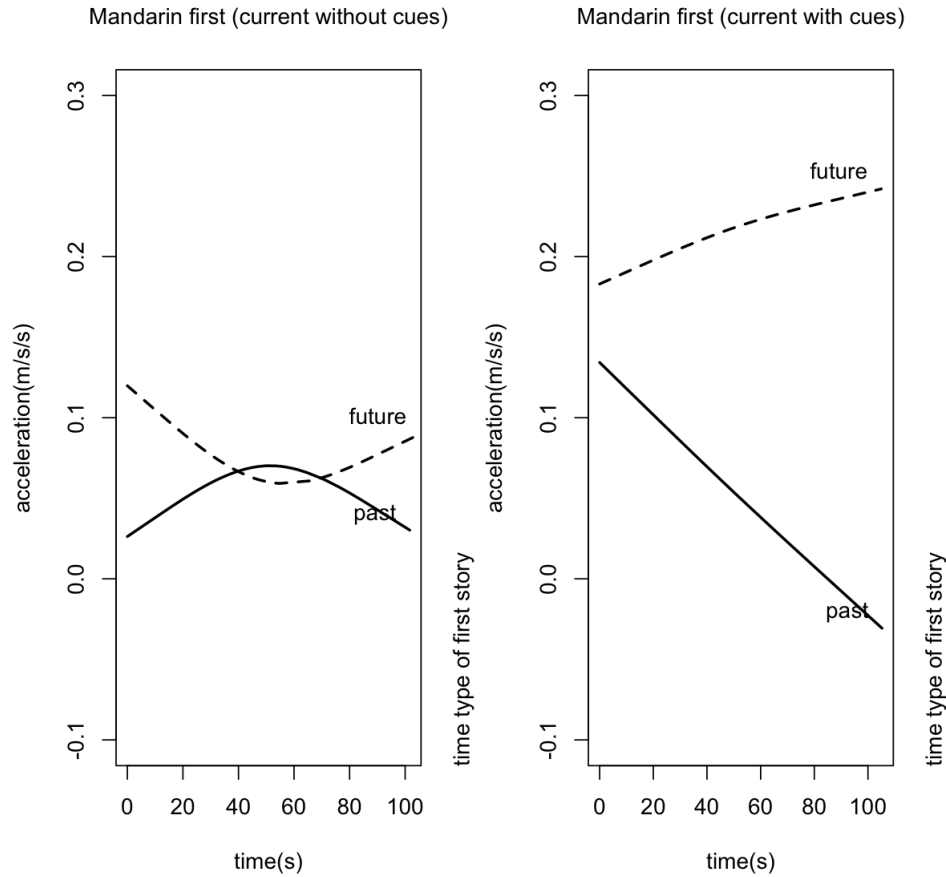
In other words, when the first story was in English, the participants' swaying directions when listening to the following Mandarin stories were consistent with the time type of the first English story. This result is consistent with the effect of the English context from the first perception task: participants in the English context swayed more forward for the future than for the past.

Table 4.13: The results of the model testing the effect of directional cues on Mandarin stories when the first story was in Mandarin, first time type: future vs. past, cues: yes vs. no, time: time variable, Y values: values on the vertical dimension.

	Estimate	Std. Error	t value	
(Intercept)	0.031054	0.0682218	0.46	
Y value	0.2089806	0.007258	28.79	***
position	0.0235028	0.0005406	43.48	***
rsc(time,3)=time	-0.0016028	0.0001806	-8.88	***
rsc(time,3)=time'	0.0017844	0.0002313	7.71	***
cues=yes	0.020312	0.0075447	2.69	**
first time type=past	-0.1115517	0.0964535	-1.16	
rsc(time,3)=time:cues=yes	0.0023733	0.0002507	9.47	***
rsc(time,3)=time':cues=yes	-0.0020724	0.0003113	-6.66	***
rsc(time,3)=time:first time type=past	0.0027865	0.0002554	10.91	***
rsc(time,3)=time':first time type=past	-0.0033163	0.0003272	-10.14	***
cues=yes:first time type=past	0.0782206	0.0106807	7.32	***
rsc(time,3)=time:cues=yes:first time type=past	-0.0053025	0.0003545	-14.96	***
rsc(time,3)=time':cues=yes:first time type=past	0.0039182	0.0004403	8.9	***

Figure 4.12 shows that when listening to the Mandarin stories that had a Mandarin story as the first story, participants swayed more back when the first story was about the future than when the first story was about the past, no matter whether the Mandarin stories had cues or not (solid lines below dashed lines). In other words, when the first story was in Mandarin, participants' swaying directions when listening to the following Mandarin stories were consistent with the time type of the first Mandarin story. Such a result is consistent with the bilinguals' behaviours in the production task part: they swayed more back for the future than for the past regardless of whether the questions had sagittal cues or not. On the contrary, when the first story was an English story, the participants swayed more forward when the first story was about the future than when it was about the past regardless of the existence of Mandarin cues in the current story.

Figure 4.12: Plots for the results of the models testing the effect of directional cues on Mandarin stories when the first story was in Mandarin. Dashed line: when the first story was about the future, solid lines: when the first story was about the past.



The Immediate Effect of Mandarin Cues

In the first perception task the immediate effect of Mandarin cues was tested, and a three-second window after each cue was analyzed. It was found that the bilinguals swayed more backward after hearing a Mandarin-future-back cue and swayed more forward after hearing a Mandarin-past-front cue. Therefore, in the current second perception experiment, the immediate effect of Mandarin cues was also tested. Three different periods of time were extracted: one second window, two seconds window and three seconds window after each cue. Linear models were tested and directional cues were found to

be not significant or nearly significant for the one-second window and two seconds windows. Only three seconds windows showed significant results. The model contained speakers as a random intercept, and whether the reading was within the three seconds or not as a fixed effect. The model that tested the immediate effect of the Mandarin-future-back cue showed a significant result (estimate 0.035947, t value 12.89). The positive estimated value means that participants swayed more back right after hearing the Mandarin-future-back cue *hou*. The result is consistent with the first perception experiment. In order to look at the immediate effect of the Mandarin-past-front cue, the same model was conducted on the Mandarin past story with cues. The model that tested the immediate effect of the Mandarin-past-front cue showed a significant result (estimate -0.008033, t value -3.268). The negative estimated value means that participants swayed more forward right after hearing the Mandarin-past-front cue *qian*. The result is also consistent with first perception experiment.

Effect of the First Story on the Six Stories

When looking at all the six stories, the model for testing the whole data contained participants as a random effect, and three fixed effects, which are values on the y-axis; the interaction between the RCS function of time variable, time type and language; and the interaction between the RCS function of time variable, time type of the first story and language of the first story. For the first stories, the time type and the language of the first story are the time type and the language of themselves. The results of the model are given in Table 4.14.

The model reveals some significant results. Values on the y axis are significant and the position of each story is also significant. More importantly, the two interactions between time variable, time type and language are both significant. The results in Table 4.14 are complex therefore the two interactions are plotted separately. In order to make a better visual comparison, the interaction between time variable, time type of the first story and language of the first story is plotted in Figure 4.13, and the interaction between time variable, time type and language of the current story is plotted in Figure

4.14. Within each figure, the interaction is plotted into two plots according to language.

Table 4.14: The results of the model testing the participants' body sway when listening to stories in Mandarin and English, time: time variable (seconds), time type: future vs. past, language: Mandarin vs. English, first time type: future vs. past, first language: Mandarin vs. English.

	Estimate	Std. Error	t value	
(Intercept)	0.0800067	0.0585881	1.37	
Y value	0.2810659	0.0049668	56.59	***
r _{cs} (time,3)=time	-0.0020529	0.0001347	-15.24	***
r _{cs} (time,3)=time'	0.0016781	0.0001675	10.02	***
time type=past	-0.030565	0.0045134	-6.77	***
language=english	-0.1855041	0.0055078	-33.68	***
position	0.0189314	0.0003885	48.73	***
first language=english	-0.1011442	0.0970357	-1.04	
first time type=past	-0.1269973	0.0827524	-1.53	
r _{cs} (time,3)=time:time type=past	0.002048	0.0001494	13.71	***
r _{cs} (time,3)=time':time type=past	-0.0009352	0.0001853	-5.05	***
r _{cs} (time,3)=time:language=english	0.0016365	0.0001807	9.05	***
r _{cs} (time,3)=time':language=english	-0.0005889	0.0002193	-2.69	**
time type=past:language=english	0.1210754	0.0078114	15.5	***
r _{cs} (time,3)=time:first language=english	-0.0014525	0.0001705	-8.52	***
r _{cs} (time,3)=time':first language=english	0.0012007	0.0002105	5.7	***
r _{cs} (time,3)=time:first time type=past	0.0014343	0.0001454	9.87	***
r _{cs} (time,3)=time':first time type=past	-0.0023237	0.0001795	-12.95	***
first language=english:first time type=past	0.1763841	0.1575557	1.12	
r _{cs} (time,3)=time:time type =past:language=english	0.000483	0.000258	1.87	.
r _{cs} (time,3)=time':time type =past:language=english	-0.0013873	0.0003185	-4.36	***
r _{cs} (time,3)=time:first language =english:first time type=past	-0.0001718	0.0002768	-0.62	
r _{cs} (time,3)=time':first language =english:first time type=past	0.0009378	0.0003418	2.74	**

Figure 4.13: Plots for the results of the model testing participants' body sway when listening to stories in Mandarin and English. The interaction between time variable, time type of the first story and language of the first story, left plot: when the first story is in Mandarin, right plot: when the first story is in English.

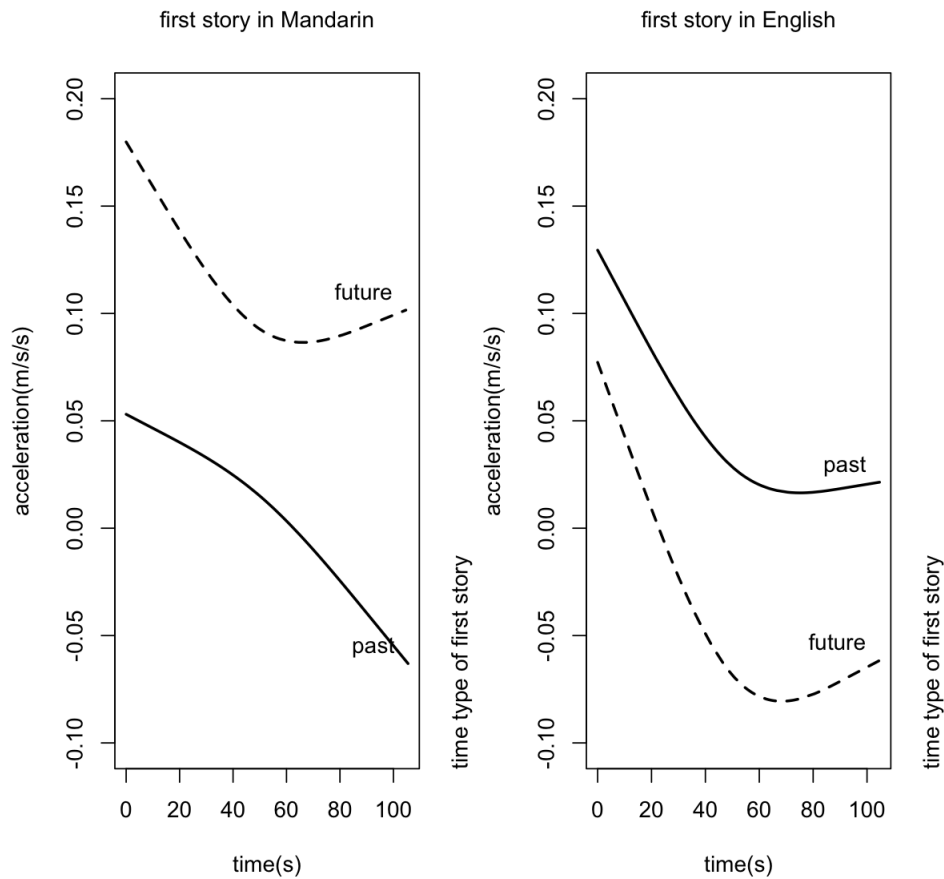
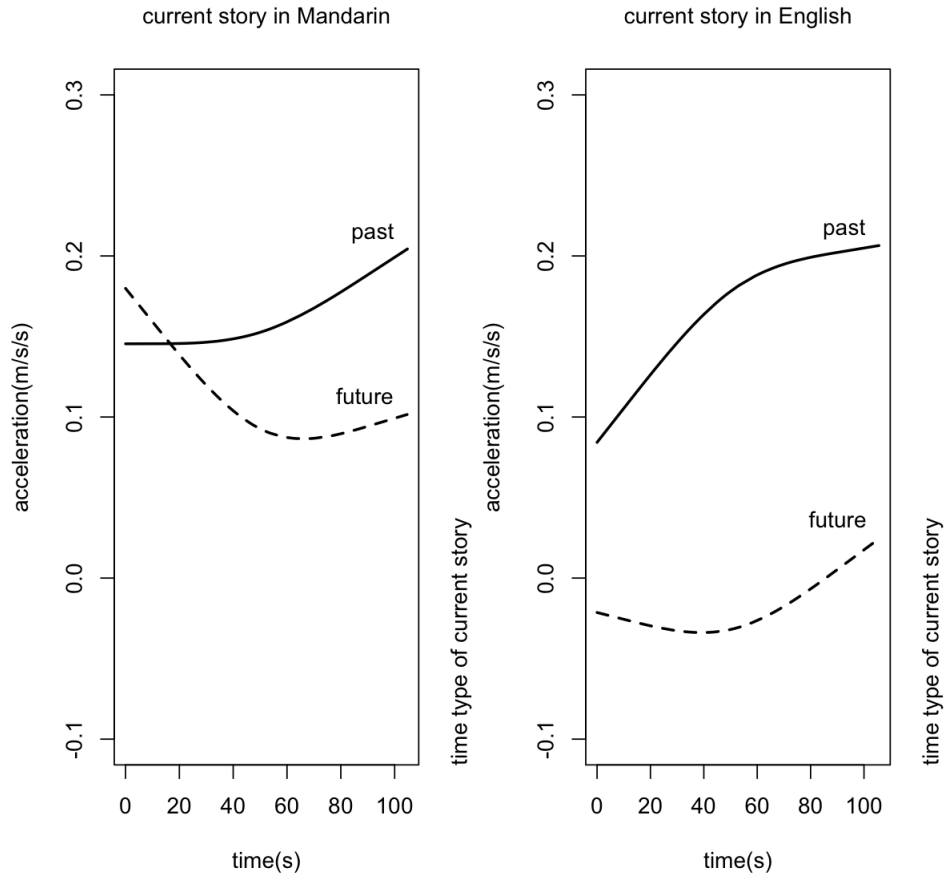


Figure 4.13 shows the significant interaction between time, time type of the first story and language of the first story. When the first story was a Mandarin story about the future (left), in the following stories the participants swayed more backward than when the first story was a Mandarin story about the past (solid line below dashed line). When the first story was an English story about the future (right), in the following stories the participants swayed more forward than when the first story was an English story about the past (dashed line below solid line). Language and time type of the first story had overall effects on the following stories.

Figure 4.14: Plots for the results of the model testing participants' body sway when listening to stories in Mandarin and English. interaction between time variable, time type and language of the current story, left plot: when the current story is in Mandarin, right plot: when the current story is in English.



Apart from the effect of the first story, which established an overall priming condition on its following stories, language and time type of each story also matter. Figure 4.14 shows that the participants swayed more forward when listening to stories about the future than stories about the past no matter what language they were listening to (solid lines above dashed lines). However, the difference between stories about the future and stories about the past was bigger when listening to English stories than when listening to Mandarin stories, which is consistent with the pointing experiment, in which it was found that the bilinguals in the Mandarin context also associated front with the future and back with the past as they did in the English context,

but not as strongly as the associations in the English context.

The results from the overall model are consistent with the results from the two models that tested directional cues. In both cases the effects of the very first story were found.

Discussion for the Second Body Sway Experiment

Time type and language of both the first story and the current story affected the participants' body movements. The first story established a priming condition on its following stories and the participants swayed their bodies according to the language and time type of the first story. At the same time, the current stories also affected their body posture. Although the participants in this experiment did not behave exactly like other bilinguals in the previous body sway tasks, if we consider things in a relative way rather than an absolute way, the two body sway experiments are consistent with each other. Based on the current experiment, the effect of language at least can be confirmed. The bilinguals' body swaying directions differ according to what language they listened to.

When the very first story affected the following stories, directional cues did not seem to affect the bilinguals' Mandarin stories: they swayed more back for the future than for the past in the Mandarin context regardless of directional cues, which is consistent with the effect of Mandarin cues in the production experiment but is inconsistent with the hypotheses. Furthermore, it also raises a question for the default temporal direction on the sagittal axis in Mandarin. The immediate effect of Mandarin cues in the current second perception task is also consistent with the first perception task: the bilinguals swayed their bodies to the corresponding directions that were suggested by the Mandarin cues right after they heard the cues.

In Mandarin, directional cues can affect people's perception of time. Findings on directional cues so far reveal similar and consistent results. In the pointing experiment directional cues had an effect on Mandarin speakers' perception of time in the Mandarin condition. The effect of directional cues on the bilinguals' body sway directions in the Mandarin context in the production task was consistent with the Moving Time model in Mandarin,

that is, future-backward and past-forward. Importantly, the overall effect of Mandarin directional cues on the bilinguals' body sway directions in the second perception task is consistent with their effects in the production task: the bilinguals swayed more forward for the past than for the future regardless of the existence of cues.

In order to test the mechanism behind the effect of directional cues, it was hypothesized that when people hear a directional cue, they will sway to the corresponding direction in the following period of time, e.g. several seconds. In order to test the hypothesis above, people's swaying data after they heard each directional cue were extracted. The immediate effects of Mandarin cues in the two perception tasks were similar. In both cases the bilinguals heard the Mandarin-future-back cue *hou* and then swayed backward in the following period of time, and they heard the Mandarin-past-front cue *qian* and they swayed forward in the following period of time. These results are consistent with the pointing experiment and therefore confirm the immediate effect of Mandarin directional cues in the implicit task.

For the effect of the very first story, it is a strong effect in the second perception task. We can see that the time type (future vs. past) of the first story interacted with the language of the first story. The effect of the first story was also found for the first perception task but it was different. The effect of the first story was stronger in the second perception task because the effect of time type interacted with language. On the contrary, in the first perception task, the only factor that varied in the first story was time type and it cannot interact with language since one session only used one language, and therefore language would not have an effect on the following tasks.

The second perception task had some differences from the first in terms of materials. Stories were re-recorded and the signal was not modified. However, the two groups of bilinguals in the Mandarin contexts showed similar results. Both groups behaved according to the Mandarin front-past and back-future temporal direction. Therefore, it is reasonable to believe that the modified sound in the first perception task had little effect on the task. Similarly, both groups of bilinguals in the two perception tasks behaved according to the Moving Ego model when the language context was English,

which was consistent with the hypotheses.

It is also worth mentioning that none of the participants in the body sway experiment participated in the pointing experiment and the experiment that will be presented in the next chapter, nor did they participate in both perception tasks.

4.4 Overall Discussion

The body sway experiments tested the effect of language, time type and cues on people's body sway when they were listening, thinking, and talking as an implicit association between mental timeline and physical space. The major aim was to see whether participants' body sway directions were congruent with the temporal direction in each language or at least the relationship between directions when processing information about the past and the future should be congruent with the relationship between the past and the future in each language. In the experiments mentioned in this chapter, body sway directions were tested but types of body sway were not differentiated based on their physical start point, that is, body sway starting from a person's feet and body sway starting from a person's hips. For these reasons, when a tracking device can only record accelerations, and people's physical heights or the heights of their upper bodies were not recorded, swaying distances are unknown but trajectories between the future and the past can still be compared.

4.4.1 Summary of the results

The body sway experiment used the results from the pointing experiment and existing studies to form its hypotheses. In order to summarise results on the sagittal dimension, Table 4.15 presents the results from the pointing task, first body-sway experiment, including the production task and the first perception task, and the second perception task. A dark grey cell indicates that the participants swayed more forward for the future than for the past, whereas a light grey cell means that the participants swayed more backward for the future than for the past. X means that the result is inconsistent with the hypotheses and n/a means not applicable. The English monolinguals

and the bilinguals are presented separately.

Table 4.15: Summary of the results from the pointing experiment, production task and two perception tasks. Dark grey: more forward for the future than for the past, light grey: more backward for the future than for the past, x: results that are inconsistent with the hypotheses, n/a: not applicable.

Task	Group/condition	Results	
Pointing task	English monolinguals		
Production task			
First perception task		x	
Pointing task	ME bilinguals in the English condition		
Production task		x	
First perception task			
Second perception task			
		Having cues	No cues
Pointing task	ME bilinguals in the Mandarin condition		
Production task			x
First perception task			n/a
Second perception task			x
	More forward for the future than for the past		
	More backward for the future than for the past		
n/a	Not applicable		
X	Inconsistent with prediction		

As we can see, the results from the pointing experiment on the sagittal dimension are consistent with existing findings. The bilinguals in the English condition behaved like the English monolinguals and the bilinguals in the Mandarin condition were affected by Mandarin sagittal cues: they associated front with the future when there were no spatial cues, and they associated front with the past when there were Mandarin-past-front cues.

4.4.2 The Production Task

During the production task, when the English monolinguals answered the questions, their body movement patterns were congruent with the Moving

Ego model in English in both the thinking and talking phases. Such results are consistent with the English monolinguals' behaviours in the pointing experiment. We can see that when thinking about and producing speech about information about the past and the future, English monolinguals' body movement patterns were consistent with the Moving Ego model in English (future-front).

Overall, there were two inconsistent results in the production task. One is that the bilinguals in the English condition behaved as if they were in the Mandarin condition (the second X in the table). The other is that, for the bilinguals in the Mandarin condition, sagittal cues did not seem to have the same effects and alter the relationship between the future and the past as they did in the pointing experiment (the third X). These two inconsistent results will be discussed below.

When the bilinguals answered the questions in the Mandarin context, their body movement patterns were congruent with the dominant temporal direction (the Moving Time model) in Mandarin in both the thinking and talking phases. Sagittal cues significantly interacted with time type; however, they always swayed more back for the future than for the past regardless of the existence of Mandarin sagittal cues in the questions (the third X).

A possible reason is that since the future-back and past-front cross-domain mappings are the dominant temporal order in Mandarin, it means that such a temporal direction and its corresponding body movement patterns accompanying speech are learned early in life and are less malleable. On the contrary, explicit associations such as from the pointing task are more affected by language than implicit associations. In other words, the pointing is affected by current language, whereas the body sway during production is affected more by native language.

Such a possibility can also explain the first inconsistent result in the production task (the second X in the table), which is, in the production task the bilinguals' behaviours in the English context are consistent with the dominant temporal direction (the Moving Time model) in Mandarin but not with the Moving Ego model in English. Since body movement patterns accompanying speech are learned early in life, native language would have a stronger effect than current language. Such a result can also be seen as the

persistence of the impact from one's native language. For future studies, this persistence of impact from one's native language on body sway patterns can be tested. For example, recruiting both early and late ME bilinguals to see if they produce different body movement patterns when talking in Mandarin.

4.4.3 The First Perception Task

In the first perception task: that is the one that had four stories, an effect on people's body movements was found. However, it was impossible to separate the effect of language and the effect of sagittal cues in the experiment. The bilinguals' behaviours in the English context were consistent with the Moving Ego model, and their behaviours in the Mandarin context were consistent with the Moving Time model. Although the effect of language and spatial cues cannot be clearly separated, the immediate effect of sagittal cues could still be tested. The results of the immediate effect of sagittal cues and future markers were consistent with the bilinguals' swaying directions in different conditions. The bilingual speakers in the Mandarin context swayed more back for the future, and they swayed even more back when they heard *hou* (back). Similarly, the bilingual speakers in the Mandarin context swayed more forward for the past, and they swayed even more forward when they heard *qian* (front).

The task had two downsides. Firstly, as has been mentioned, it was impossible to separate the effect of language from that of spatial cues. Secondly, there might be a potential effect of modified voice on people's body movements. If people found the voice was unreal or unattractive, it was possible that they would increase or decrease body movements. However, this should not be a problem. For this issue, a couple of native Mandarin speakers were asked for their opinions for the modified sound, and both of them thought that the modified female voice was natural but a bit unfriendly, which was also consistent with the fact that the modified sound sounded monotone. In order to address this issue, in the second perception task only unmodified sound was used and it showed consistent results with the first perception task, which should be able to eliminate the possibility of the effect of the modified signal.

We can see that the English monolinguals did not behave according to the Moving Ego model during the perception task (the first X in the table). This unexpected result is unclear and it probably had to do with the design of the experiment. This issue will be discussed in Chapter 6.

If we look at English monolinguals' results from the production task, it can be seen that their associations between time and sagittal direction were consistent with the Moving Ego model in English, which is also consistent with the pointing task.

4.4.4 The Second Perception Task

In the second perception task: that is the one that had six stories, the methodology was improved. Neutral positions were captured more accurately, and the effect of language and the effect of directional cues can be separated. One difference was that the experiment used randomized orders of stories for practical reasons. However, interestingly when the first story was in different languages, the bilinguals behaved according to the language of the first story in the following stories. In other words, the first story, which was also the language that was used to contextualize the whole experiment had a strong lasting effect on people's body movement behaviours.

This was probably because of the constant changes in language and time type story by story, and the stories were similar to one another, especially the Mandarin stories with cues and the ones without cues. As a result, only the very first story gave them the strongest impression. The other reason is that since all the instructions between stories were pre-recorded and repeated, the interaction between the experimenter and each participant was the last REAL interaction before each session started. This fact is particularly important since interaction with a real human is likely to give a stronger impression than the pre-recorded instructions. The language used by the experimenter also matched the language of the first story. Therefore, the experimenter's interaction gave them a strong impression of the context.

If we look at the bilinguals in the English condition, their behaviours were consistent with the behaviours from the bilinguals in the first perception task. Both groups of bilinguals behaved according to the Moving Ego

model in the English condition. Both groups of bilinguals (from first and second perception tasks) show consistent effects of language on body movement patterns

The overall effect of directional cues was not as predicted when both time type and language of the first story were considered: they still showed a future-back association even when there were no sagittal cues (the last X in the table). A possible reason has been given earlier, which has to do with the strong effect of native language. The immediate effect of directional cues in the Mandarin story was also tested, and the result was consistent with both the dominant temporal direction in Mandarin and the first perception experiment.

4.4.5 Differences between Tasks

The current body sway experiment shows that there were differences between the tasks and the differences could potentially explain some of the inconsistent results. Such a view has been mentioned earlier in the current chapter before presenting the experiments.

Explicit Tasks vs. Implicit Tasks

In the pointing experiment, it was found that even in the Mandarin condition, the bilinguals explicitly associated the future with front and the past with back when there were no directional cues, whereas in the second perception task in the current body-sway experiment, the bilinguals swayed more backward for the future than for the past when there were no directional cues, which was also found in the production task. Such a difference might have to do with the difference between explicit tasks and implicit tasks.

In the pointing task, which tested participants' explicit opinions on the relationship between concepts, participants were more affected by the language of the task. On the contrary, in the body sway experiment, which tested participants' implicit associations between time and directions, the effect of native language was stronger than the effect of current language since body movement patterns during speech are learned early.

Production Tasks vs. Perception Tasks

Although implicit and explicit tasks have different mechanisms, for example, people can give more conscious opinions in explicit tasks and they were highly likely to produce conscious body movements; within implicit tasks, the production task was also different from the perception tasks.

Compared with the production task, the participants needed to concentrate on the stories in the perception task, which means they were constantly receiving information and processing these linguistic materials. Therefore, the language of the task could have more of an effect in the perception tasks, which involved the processing of auditory materials, than in the production task, which was related to talking. Such a fact could explain the same group of bilingual speakers' inconsistent results between the production task and the first perception task in the English conditions. The bilinguals were more affected by the language of the task in the perception task and therefore they swayed according to future-front and back-past mappings in English when listening to the English stories. On the contrary, the bilinguals were more affected by their native language in the production task. Therefore, they swayed according to future-back and past-front mapping in Mandarin when they were thinking and talking in the English context.

To summarize, the four different parts of the experiment seemed to reveal different but broadly consistent results with some exceptions (except for the unexplained behaviours from the English monolinguals in the listening task). Different tasks have different mechanisms, and therefore people were affected by different factors across experiments. Firstly, language can affect how people sway their bodies. People sway to different directions when processing information about the future and the past according to what language they are processing. Since English and Mandarin have different associations between time and space, language can alter the relationship of swaying forward and backward between the future and the past. The effects of language were found in passive listening, active thinking and active talking. The English monolinguals' active thinking part replicated findings from Miles, Nind, and Macrae (2010), and it was extended to bilingual speakers whose two languages emphasize different temporal sequences. Secondly, the

overall effects of directional cues between the production task and the second perception task are consistent and interpretable. Previous findings from Lai and Boroditsky (2013) and our pointing experiment suggest the immediate effect of directional cues in explicit tasks, whereas the current body-sway experiment revealed a similar finding in implicit tasks. The immediate effects of directional cues are meaningful for the bilinguals in both perception tasks. When actively processing temporal information in the production experiment, Mandarin directional cues did not affect the bilinguals' swaying directions in the Mandarin context. The findings suggest that one's native language could still have strong effects on body movements. The experiment suggests that language can affect subconscious body movements. A remaining question is whether even bigger movements can still be affected. In the next chapter, an experiment that involved large body movements will be introduced.

Chapter V

Walking while Listening to Temporal Information

In the previous chapter, I presented results from a body sway experiment that had three tasks. Evidence suggests that temporal information, both with and without directional cues, can subconsciously affect people's body movement directions. In the current chapter, an experiment which tests how quickly people walk when listening to stories about the past and the future will be presented. Since temporal information can subconsciously affect people's body movements, the remaining question, which is the third question that was asked at the end of Chapter 2, will be answered. In addition, Question b under Question 4 will also be answered.

3. How general is the effect of temporal perception on body movements?
 - (a) Do English speakers walk faster when listening to information about the future than when listening to information about the past?
 - (b) Do Mandarin-English bilinguals walk faster when listening to information about the future than when listening to information about the past in English?
 - (c) Do ME bilinguals walk faster when listening to information about the past than when listening to information about the future in Mandarin?
4. Could spatial cues in temporal expression affect how Mandarin speakers perceive time?
 - (a) Do Mandarin speakers associate different directions with temporal information that lacks spatial cues than when the temporal information contains the spatial cue front (or back)?

- (b) If yes, can the presence of spatial cues in temporal expression affect Mandarin speakers' body movement patterns (walking)?

Many existing studies have demonstrated that people's walking speed can be affected if people are performing a dual-task such as reading, listening, talking or using other devices such as a mobile phone while walking (Schwebel et al., 2012; Schaefer, Jagenow, Verrel, & Lindenberger, 2015). People's walking speeds dramatically decrease if they read and text on a mobile phone (Schabrun, van den Hoorn, Moorcroft, Greenland, & Hodges, 2014). Their speeds can also be affected if they are listening to music when walking (Neider et al., 2011). Using a mobile phone with a touch screen and reading large sized texts will also decrease walking speed (Schildbach & Rukzio, 2010). In short, a dual-task involving walking and additional cognitive processing would influence people's walking speeds. However, such an effect might influence people differently. Studies have showed that children's and elderly people's walking speeds are more affected by the cognitive load in a dual-task than those of young adults. This is probably because children have not developed a sophisticated sensory-motor system that is based on experience, whereas elderly people have a weakened sensory-motor system and they need more conscious control in a walking task (Lindenberger, Marsiske, & Baltes, 2000).

On the other hand, other factors in a single task, such as when an elderly stereotype is activated, may cause people such as young adults to walk more slowly than they normally would (Bargh, Chen, & Burrows, 1996; Mussweiler, 2006). Such a phenomenon suggests that people's behaviours could be automatically activated by the context and a particular type of stereotype. Some other studies such as Gibbs (2013) looked at the effect of metaphorical interpretation such as LOVE IS A JOURNEY on walking and imagined walking, and they found that people who were primed with a successful love story with the metaphor walked further and longer than people who were primed with an unsuccessful love story with the metaphor. More importantly, no differences were found for the stories that did not use the metaphor. The results found by Gibbs were consistent with existing studies on metaphorical comprehension. For example, Wilson and Gibbs (2007) found that the par-

ticipants were faster to read a metaphorical phrase if the action described by the phrase (e.g., push the argument) matched a previous body action (e.g., push movement). These studies suggest that understanding of abstract movements is based on embodied simulation of metaphorical action and real action.

The experiment presented in the current chapter was designed to further explore the relationship between action and the comprehension of conceptual metaphor as TIME IS SPACE. A previous study (Rinaldi, Locati, Parolin, Bernardi, & Girelli, 2016) found that people's walking a step forward and backward can be consistent with processing information about the future and the past respectively. The research question of the current study is: Can temporal direction, that is not overtly described by metaphorical movements but is related to directions through cross-main mappings, influence real walking? In order to answer this question, another experiment was designed and it used a dual task to test the effects of listening to fictitious stories about the past and the future on people's walking. If temporal information embedded in auditory materials can also affect people's walking, it also means that the associations between time and direction are strong enough to influence behaviours even when information about direction and movements is minimal.

The current experiment used a dual-task. The prediction is that if action (or embodied simulation of metaphorical action) is necessary for the comprehension of metaphorical information, such as the body sway during listening, then the direction that is described by temporal information through space-time cross-domain mapping can also facilitate or block the direction of walking. The walking experiment will use the existing (e.g., Miles, Nind, & Macrae, 2010) body sway experiment to form its hypotheses.

5.1 Hypotheses

- (a) English monolinguals will walk faster when listening to a story about the future than when listening to the one about the past, which is based on the effect of the processing of temporal information on body movements (Miles, Nind, & Macrae, 2010; Rinaldi et al., 2016).

- (b) Bilinguals in the English context will behave like English monolinguals.
- (c) Bilinguals in the Mandarin context will walk faster when listening to a story about the past than when listening to one about the future.

The current experiment chose to test people's walking speeds. One advantage was that changes of speeds can be observed throughout the course of the walking task, and people's speed trajectories can be calculated and compared between different experimental conditions. When giving participants auditory stimuli at the same length, which means they walk at equal lengths in time, higher speeds would also mean longer distances. Since lengths in time of walking were only measured during imagined walking in the previous study (Gibbs, 2013), the current experiment tested real action and did not test lengths in time of walking.

Clinical tests on people's walking speeds usually compare people with certain diseases to people in normal health, and people can be tested on a treadmill (e.g., Kang & Dingwell, 2008; Tester, Barbeau, Howland, Cantrell, & Behrman, 2012). Such a method is practical when collecting kinetic parameters and physiological data (Riley, Paolini, Della Croce, Paylo, & Kerrigan, 2007); however, since the current experiment tested the potential effect of directional information embedded in temporal information, using a treadmill would inform people that the experiment was measuring walking patterns and the purpose would be too obvious. Therefore, the experiment had to use some other methods without letting participants know what the true purpose of the experiment was and at the same time to compare speeds across different conditions. The solution was to use two approaches and one was that the experiment did not use a treadmill. The other approach and the design of the experiment will be introduced in the following methodology section.

5.2 Methodology

Participants

Twenty New Zealand monolingual English speakers and 20 Mandarin-English bilingual speakers were recruited by using public signs around the campus of the University of Canterbury and passing the information to the first year

linguistic undergraduates. Their participation was in exchange for shopping vouchers. All the participants were asked what languages they could speak before they came to the experiment, and the bilinguals filled out a questionnaire before the experiment. The questionnaire was same as the one that was used in the previous pointing task and body sway experiment. It asked six agree/disagree questions. The inclusion criterion was whether their answers to at least four questions indicated their Mandarin was stronger than their English.

As mentioned, the experiment used some belt and braces approaches and one of them was to not use a treadmill. The other approach was that the participants were told that they would be tested on how well they can remember the content of the stories, which was also the purpose that was mentioned in the public sign (see Appendix). As a result, they were told that they needed to remember as much of the content as they could, and there would be questions about the stories at the end. The experimenter used English when arranging the participants. The bilinguals did the experiment twice in different languages, and the language used by the experimenter was same as the language of the corresponding session. The two sessions for each bilingual were at least a week apart. In order to counterbalance, half of the monolinguals listened to the story about the future first, half of the bilinguals did the experiment in the English session first, and within each session half of the bilinguals listened to the story about the future first.

Materials

The current experiment was conducted before the second perception experiment, that is the one that had six stories. The materials in the current study were four short stories, which were same as the stories used in the previous body sway experiment in the first perception task. The four stories are in the Appendix. Two English stories were played to the monolinguals, and the same English stories and two Mandarin stories were played to the bilinguals. Two English stories had no directional cues and the Mandarin stories had directional cues. The biggest difference in English and Mandarin involved the Mandarin directional cues, and therefore, it was to maximize the chance

of an effect. If no clear effects could be found here, then the chances of getting one when there were no cues present in Mandarin were fairly low. The bilinguals needed to come to the experiment twice. All the four stories had different content but were connected. Each Mandarin story contained ten time-related phrases that had directional cues and one story was about the past and the other was about the future. The English stories had no time-related phrases, and one was about the past and the other was about the future. Stories were read by native speakers and recorded by using Audacity. Each story was 90 seconds; the two Mandarin stories were modified in order to make them 90 seconds long. The four stories are as follows:

1. A Mandarin story about the past that contained Mandarin-past-front cues such as ‘three days ago’, ‘the day before yesterday’ etc.
2. A Mandarin story about the future that contained Mandarin-future-back cues such as ‘the day after tomorrow’, ‘in five days' time’ etc.
3. An English story that was about the past, but which contained no sagittal cues.
4. An English story that was about the future, but which contained no sagittal cues.

There was an instruction at the beginning before the first story, read by a native English speaker in the English session, and a native Mandarin speaker in the Mandarin session.

Equipment

The devices used were an audio player with a pair of earphones and a Samsung GT-S5660 mobile phone. The mobile phone had a built-in antenna which could receive GPS signals and an App called My Tracks was installed on the phone. The App could use GPS signals to track the phone, including its distance, speed, time, latitude, longitude and altitude. The accuracy rate was within 4 metres and it was tested each time before a participant arrived to make sure that it was within this distance. A wooden board was designed with a plastic holder on top of it, which was the same wooden board used in

the second perception task in the body sway experiment. It was placed in a backpack which was carried by the participants when walking. The height of the board was slightly higher than that of the backpack; as a result, the plastic holder would be on top of the backpack when the board was in the backpack, and when the phone was placed in the holder it would still receive signals. The mobile phone was placed inside the plastic holder after the participants put on the backpack, and therefore, they did not know anything about the tracking device.

Procedure

The experiment required the participants to walk for a distance. As mentioned, one of the two approaches was to not use a treadmill. The solution was that the experiment would take place in an open field, which also had the advantage that GPS satellite signals would not be interfered with because there would be no trees, buildings and telegraph poles. The location of the experiment was at Ilam Fields, which are multi-functional fields for many types of sports and situated next to the University of Canterbury. The participants were asked to meet the experimenter at the entrance near the corner of the fields. When they arrived, the participants had to read an information sheet and then they were asked to sign a consent form. The bilinguals were asked to complete a questionnaire about their use of languages. The English monolinguals did the experiment once only and the bilinguals did it twice: once in each language. The consent form and questionnaire were only given in the first session.

The experimenter briefly informed the participants of the procedures of the experiment. They were told that the audio file they were going to listen to contained an instruction, three beeps, and two stories. Then the experimenter told the participants that the path went from somewhere not far from the entrance diagonally to the corner on the other side of the fields. The starting point was still a certain distance away, that is about 15 to 20 metres away from the entrance, because there were trees near the entrance and they might influence the GPS signal. The experimenter also told them not to worry about approaching the corner on the other side since the stories

would be short and would finish when they were somewhere in the middle of the fields. Then they were asked to put on the backpack before the tracking phone was placed in the plastic holder. They were told that the holder was for the audio player in case they accidentally touched the screen and stopped the audio. However, after they put on the backpack, the tracking function was immediately turned on by the experimenter on the phone and the experimenter put the phone in the plastic holder, and at the same time, started to play the audio file and put the audio device into the side pocket on the backpack.

The instruction at the beginning of the audio file told the participants that they were going to hear three beeps and two stories, and when they heard the first beep, it meant they needed to start walking and the first story was about to begin; the second beep meant that the second story was about to begin, but they would not need to stop walking, and the third beep meant that the second story had ended and they must stop walking. The instruction also told them to stand where the stories finished and the experimenter would approach them. The instruction emphasized that they needed to pay attention to the stories and remember the content as well as they could. The experimenter followed the participants when they were walking, and kept about 10-15 metres away from them. Therefore, when the second story ended, the experimenter was able to approach them quickly, turn off the tracking function and remove the phone from the holder before the participant took off the backpack.

The bilinguals were given a list of questions regarding the content of the stories, which was a deception in order to give them the impression that they would need to remember the content in the second session. They were told the real purpose of the experiment after they came back and finished the second session in the other language a week later. Half of the English monolinguals listened to the future story first. For the bilinguals, half of them listened to the future story first in one language, and the rest listened to the future story in the other language. Half of the bilinguals did the English session first and the rest did the Mandarin session first in order to counterbalance. All the participants were tested in afternoons when the weather was suitable. No experiments were conducted on rainy days, the first days after rainy days or

in the morning, which was to avoid any potential effects of muddy ground on people's walking speeds.

Model Fitting Strategies

Preliminary analyses suggested that people walked at different speeds when listening to the two stories. Therefore, whether a story was the first story or the second story they listened to was added as a potential factor. Other factors were also included such as time type (future vs. past) and time variable. The priority of the model was to test the interaction between time variable, time type and which story they were listening to. The model revealed significant three-way interactions which meant that the order of the two stories had an effect. In addition, the participants did not stop walking when hearing the second beep, which meant that they stood still and started walking when listening to the first story, but they just kept walking when the second story began. The pause between the two stories was too short, which was the same problem as in the perception experiment in the previous body-sway experiment, and the first story might have had a strong influence on the second one. For this reason, only results from the first story will be reported. The initial model for testing speed tested a three-way interaction between language, time type and time variable; however, it did not reveal significance. Therefore, the interaction between time type and time variable was separately tested for different language groups/conditions. By doing so, walking speeds can be compared between the future and the past, and the interactions can be compared between language groups. If the interaction was found to be significant, the RCS function of the time variable would be tested and an ANOVA test would be conducted to test the difference between the two models.

5.3 Results

The program on the tracking device could receive signals from satellites and then record a person's walking speeds, total time spent, distance, and by constantly monitoring latitude and longitude, the program could map a person's walking path onto a Google map. One problem with the device was that in

order to capture people's speeds accurately, the phone needed to be moving in order to constantly receive signals from satellites. It means that as long as a person kept moving, the accuracy would be equal to 4 metres, which was the smallest accuracy range. If a reading was captured when the accuracy range was greater than 4, then the reading was not very accurate because the satellites could not triangulate the device accurately. When looking at the data, it was noticed that the first reading from every participant's first story was captured when the accuracy range was greater than 4 metres which was logical since the phone can only record speeds accurately as long as the person is moving, and the first reading was not accurate when the person was standing still. As long as the participants started walking, the accuracy range became 4 metres from the second reading till the second to the last reading. For this reason, the initial reading of the first story from every participant was removed from the data. The experiment used recommended settings on the program with two seconds for minimal time intervals and five metres for minimal distance intervals. The device recorded most participants' speeds every 4-5 seconds; and as for some of the participants who were slow walkers, sample rates varied between 6 and 7 seconds. Therefore, different participants who walked with different speeds would have different numbers of sampling points. Faster walkers had shorter time intervals, thus they had more sampling points, whereas slower walkers had longer time intervals and had fewer sampling points. To solve the issue, time variables used in linear models would be the position of each sampling point divided by the total numbers of sampling points, in other words, proportion of time. The order for presenting the result would be English monolinguals, bilinguals in the English context, and then bilinguals in the Mandarin context.

English Monolinguals

The model for testing the English monolinguals tested the interaction between time type and the RCS function of the time variable. The results of the model are given in Table 5.1.

Table 5.1: The results of the model testing the English monolinguals' walking speeds when listening to the first story, time type: future vs. past, time: proportion of time.

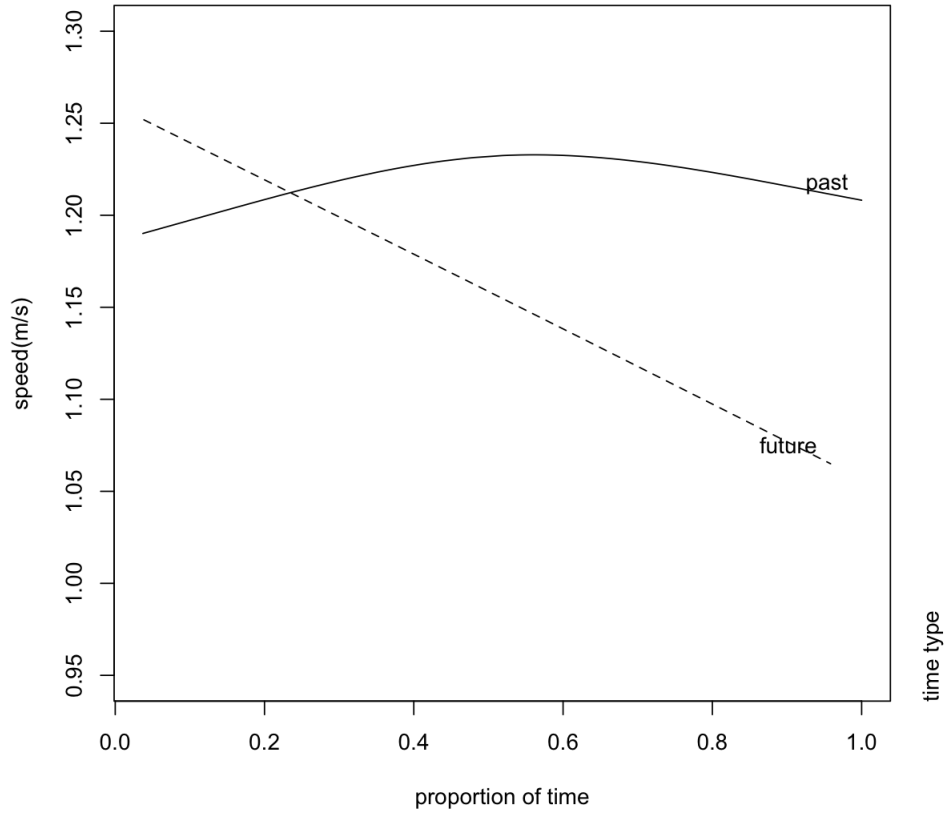
	Estimate	Std. Error	t value	
(Intercept)	1.259603	0.041789	30.142	***
time type=past	-0.073697	0.058781	-1.254	
rsc(time,3)=time	-0.201675	0.055806	-3.614	***
rsc(time,3)=time'	-0.002038	0.068914	-0.03	
time type=past:rsc(time,3)=time	0.315117	0.076714	4.108	***
time type=past:rsc(time,3)=time'	-0.125029	0.094972	-1.316	

The results of the model clearly show a significant interaction between time type, and proportion of time (t value = 4.108). In order to understand the complex results of the model, the results are plotted in Figure 5.1.

Figure 5.1 clearly shows different patterns for the English monolinguals between their listening to the story about the past and their listening to the story about the future. The initial and the final readings for every participant were removed since both were recorded when the accuracy range was greater than 4 metres, therefore speed does not start and end with 0.

The plot shows that the English monolinguals who listened to the story about the past (solid line) started with relatively (but not significantly) lower speeds than those who listened to the one about the future (dotted line) at the beginning, and they slightly increased their speeds and maintained them until they finished the first story. On the other hand, the English monolinguals who listened to the story about the future started with relatively higher speeds, and decreased them dramatically throughout the entire first story. Overall, the English monolinguals who listened to the story about the past walker faster than those who listened to the story about the future.

Figure 5.1: Plots for the results of the model testing the English monolinguals' walking speeds when listening to the first story. Solid line: past, dotted line: future.



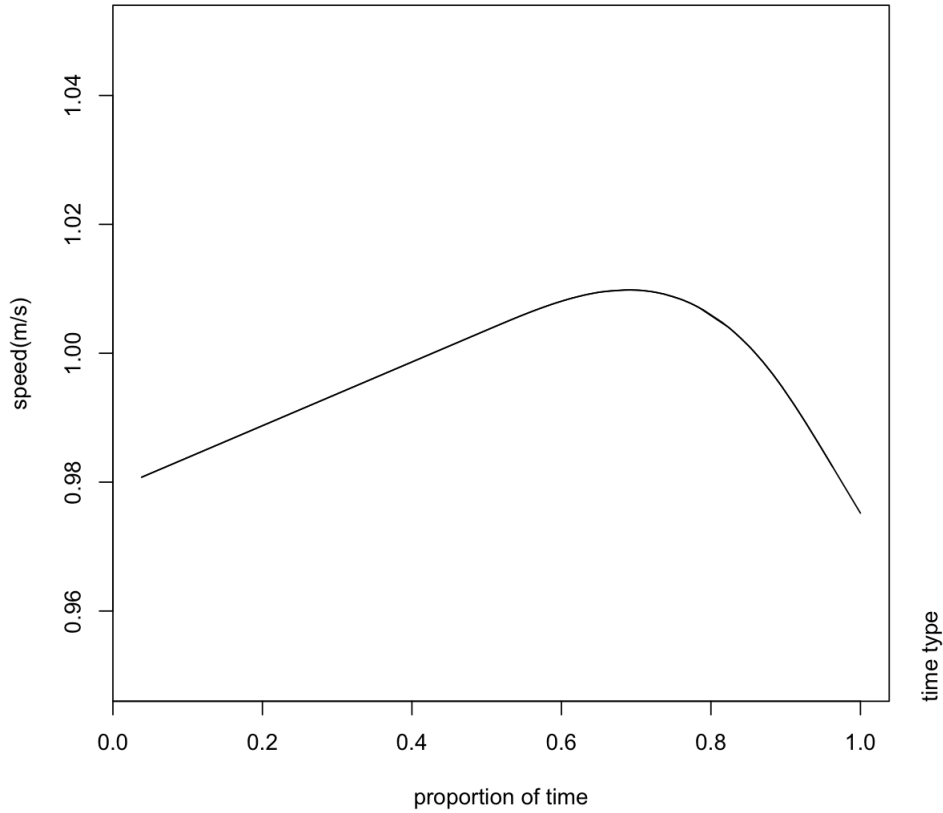
Bilinguals in the English Context

Time variable and time type were tested, however, time type was not found to be near-significant. Only the RCS function of the time variable was near-significant. The results are given in Table 5.2.

Table 5.2: The results of the model testing the bilinguals' walking speeds in the English condition when listening to the first story. Time: proportion of time.

	Estimate	Std. Error	t value	
(Intercept)	0.97886	0.05699	17.177	***
rsc(time,3)=time	0.04945	0.02737	1.807	.
rsc(time,3)=time'	-0.09851	0.05118	-1.925	.

Figure 5.2: Plots for the results of the model testing the bilinguals' walking speeds in the English context when listening to the first story.



The result shows that the bilinguals in the English condition showed a near-significant tendency to first increase their speeds and then decrease them, regardless of time type. The moving trajectory is plotted in Figure 5.2.

Bilinguals in the Mandarin Context

The linear models were tested and ANOVA tests were performed. Both time variable and time type were tested. However, none of the factors was found to be significant. In order to look at the overall picture for the bilinguals in the two sessions, their data for the first stories in the English session and in the Mandarin session were combined and linear models were conducted on the newly combined data. When adding every factor into the model, for example, time variable, time type and language, the interaction between them was

not found to be significant. Only language was found to be significantly affecting the bilinguals' walking speeds. It seems that the bilinguals in the English condition walked significantly faster than when they were in the Mandarin condition for both stories about the future and those about the past. Therefore, separate models were tested between the English story about the future and the Mandarin story about the future, and between the English story about the past and the Mandarin story about the past. Both models had only the language condition as the fixed effect. The result of the first model reveals that the effect of language was significant (estimate 0.05923, t value 4.666). The result of the second model also reveals that the effect of language was significant (estimate 0.04, t value 2.918). The positive estimate values suggest that when listening to the stories about the future and the past, the bilinguals walked significantly faster when listening to the English stories than when listening to the Mandarin stories.

Since both English and Mandarin stories had similar word counts, it was suspected that the English stories might have higher numbers of syllables per second or especially, have higher numbers of stresses per second. Some studies (e.g., Styns, van Noorden, Moelants, & Leman, 2007) have shown that people can synchronize their pace with the tempo of musical stimuli during walking. It might also be possible for people to match their pace with the sentence stress patterns in auditory linguistic materials. If the English stories had more stressed words, then people would certainly walk faster when listening to the English stories, since it is possible that their footsteps might match with each stress. Therefore, the numbers of syllables and the numbers of stressed words were both counted, and the numbers are listed in Table 5.3.

Table 5.3: Syllable number count and stressed word count for all the stories.

Stories	Syllables	Stressed Words
Mandarin story about the past	490	84
Mandarin story about the future	505	91
English story about the past	369	134
English story about the future	406	139

The table shows that compared with the Mandarin stories, the English stories had fewer syllables but more stressed words. It seems that numbers of stressed words may be an important factor that influenced the bilinguals' walking speeds. Given that all the stories had the same length, having more stressed words means more rapid stresses in the English stories. It is possible that people were trying to match their speeds with the tempo that was introduced by the stories. More importantly, differences in the numbers of stresses still can also explain the bilinguals' similar speeds between the two English stories, and between the two Mandarin stories.

Directional Cues and the Effect of Momentum

Evidence from the previous body sway experiment suggests that temporal information can make people sway their bodies differently, whereas directional cues could have an immediate effect. The current walking experiment also tried to find a combined effect of language and directional cues. The effect of directional cues on people's walking speeds was also tested by looking at a three seconds window after each directional cue in the Mandarin stories; however, there were no significant effects of cues on speeds.

5.4 Discussion

The current walking experiment reveals some interesting results. Because of the short interval that existed between the two stories, which was similar to the first perception experiment in the body-sway experiment, the first story had an effect on the second story and therefore recorded data from the second story became unreliable. As a result, data analyses were only conducted for the first story that the participants listened to.

Different groups of participants revealed different results. When listening to the first story, the English monolinguals increased their speeds when the story was about the past and they decreased their speeds when listening to the one that was about the future. When comparing the bilinguals' results in the English condition with those in the Mandarin condition, it was found that overall they walked faster in the English condition than in the Mandarin

condition.

The Unexpected Results from the English Monolinguals

Based on the results, we can see that the English monolinguals' behaviours were inconsistent with the hypotheses and existing studies. Nevertheless, the English monolinguals in the walking experiment behaved consistently with the English monolinguals in the first perception task in the body sway experiment. Based on the existing theories of mental timeline and space-time cross-domain mappings, these unexpected results remain unexplained and need to be tested in future studies. One possible reason is that it could be caused by the experimental stimuli. Since the materials in the current study were not designed as minimal pairs, and that means there were other possible unknown factors in the stories affecting the participants. For example, the participants might prefer one story more than the other because of the content, or they might feel sympathy for one character over the other. These uncontrolled factors could affect the monolinguals (in both the sway and the walking experiments) in unknown ways and therefore the results collected from these experiments should be treated as preliminary results only. This issue will be further discussed in Chapter 6.

The Effect of Stressing Patterns

Time type (future vs. past) had no effects on the bilinguals. Nevertheless, it was found that the English stories had more stressed words and therefore had faster tempo; whereas the Mandarin stories had fewer stressed words and therefore had slower tempo. This could be the reason for the bilinguals in the English condition walking faster than when they were in the Mandarin condition.

If we look at the numbers of stressed words in each story, the biggest difference is between the English stories and Mandarin stories. The English stories have more stressed words than the Mandarin stories. However, the difference is not great between the story about the future and the one about the past within each language, which also suggests that the numbers

of stressed words might have had an effect on the bilinguals, given the fact that they walked equally fast for the two stories in English, and for the two stories in Mandarin. There is no evidence suggesting that stressed words could also have an effect on the English monolinguals since the current study only tested the English monolinguals in one language. Despite the fact that so far no experimental evidence has been collected to reveal the effects of auditory linguistic materials on people's walking speeds, studies (e.g., Styns et al., 2007) have found that rhythmic auditory stimuli such as music can affect people's walking speeds. Since language and music share similar dimensions such as pitch, intensity and rhythm, it is reasonable to believe that the numbers of stressed words may be an important factor affecting the bilinguals in the current experiment.

The effect of temporal information on peoples' walking speeds does not seem to be quite straightforward. The results of the statistical models suggest that temporal information in the stories had no (or wrong) effects on the English monolinguals in both the walking experiment and the previous body sway experiment. They did not behave according to the Moving Ego model when listening to the stories. On the contrary, it seems that in the current study the stress patterns of the auditory material might have had a strong effect on the bilinguals. However, the question is, why did not stress patterns affect the English monolinguals? Studies have found that English and Mandarin are different in terms of sentence stress, which is rhythm. Speakers of the two languages process rhythm differently. For example, Chen, Lerman, Gilbert, and Robb (2001) found that the acoustic characteristics of English sentence stress produced by ME bilinguals were affected by the acoustic characteristics of Mandarin sentence stress, suggesting that bilinguals process rhythm differently in their native and non-native languages. In the current study, the bilinguals' different experience of sentence stress from the two languages might make them pay more attention to rhythmic patterns than the English monolinguals.

The inconsistent effect of temporal information and stressing patterns between the English monolinguals and the bilinguals also seems to suggest that the effect of the processing of temporal information on bodily movements might not be general. Walsh (2003) and Bueti and Walsh (2009) suggest that

space, time and number share the same cortical metrics that are related to action in reachable space. Since walking is a relatively larger movement compared with body sway and pointing, the inconsistent effect of temporal information during walking seems to be reasonable. In addition, if we take the problem of the current experimental design into consideration, stories were not designed as minimal pairs and therefore what was compared was not solely the difference between the past and the future. The effect of temporal information on walking speeds remains unclear and requires further studies.

The current experiment only tried to create an ideal situation for people to walk while listening by reducing other factors as much as possible. The experimental stimuli had their own flaws: they were not in minimal pairs, and therefore these results should be interpreted with caution. There are other individual differences, for example, some people do not like sunny days and dazzling sunlight might make people walk slowly, whereas other people might find it comfortable to walk in an open field on a sunny day. Some of these factors can be tested in future research, whereas others might never be known. Future research can make improvements by conducting the experiment in a more controlled situation, and future research should design materials as minimal pairs and pay more attention to the tempo of the auditory stimuli and use a training session to establish a baseline speed for each individual. The current walking experiment did not test the separate effects of language and directional cues for one reason: the experiment was designed to maximize the chances of an effect. The greatest difference between the body-sway experiment and the current walking one in terms of results is that in the last experiment we can see clear effects of temporal information on body movements, whereas in the current one the effect of temporal information on the bilinguals' walking speed is not clear, and Mandarin directional cues seemed not to have an effect. English monolinguals did not behave according to their mental timeline either. It is also worth mentioning that when testing people's body movements, people needed to put on a blindfold, which was to encourage body-sway; but for walking there was not such a corresponding strategy. When people walk, the effect of temporal information requires changes of speed. There are also other factors able to change people's speed: physical tiredness, cognitive load and the tempo of auditory stimuli. In the

current experiment it seems that the tempi of the stories might have affected the bilinguals.

In the next chapter, I will summarize the results from the three experiments that were conducted for the current study, answer questions that were mentioned in the second chapter and discuss the connections and differences between them as well as the implications of the current study.

Chapter VI

Overall Discussion and Conclusion

In the current chapter, I will first briefly talk about the findings from the three experiments and at the same time answer several questions that were asked at the end of Chapter 2. When summarizing the findings, I will relate them to the existing studies that look at the connection between time and space in different languages. I will answer each question by discussing the results from the three experiments that were tested and presented in the previous chapters. After that, I will discuss the relationship between the current findings and CMT and embodied cognition. I will also provide suggestions and possible research questions for future research. Finally, I will discuss the effect of language on perceptions of time and the contribution of the current study.

6.1 *Answering the Questions*

With the results collected from the explicit task, the two perception tasks, the production task and the walking experiment, I return to the questions asked earlier in Chapter 2 and will now answer them. However, before answering the questions, it is necessary to remind readers of the results of the current study. The results from the pointing experiment are summarized in Table 6.1 and those of the sagittal dimension from all the three experiments are summarized in Table 6.2.

Table 6.1: A summary of the results collected from all the conditions across language groups. Grey colour: the results that are inconsistent with the hypotheses, n/p: no preferences, n/a: not applicable.

Group	Dimension	Result-any direction condition		Result-restricted conditions	
English monolinguals	sagittal	Front for the future more often than for the past		Front for the future more often than for the past	
	vertical	Up for the future more often than for the past		Up for the future more often than for the past	
	transverse	Right for the future more often than for the past		Right for the future more often than for the past	
Bilinguals in English	sagittal	Front for the future more often than for the past		Front for the future more often than for the past	
	vertical	Up for the future more often than for the past		Up for the future more often than for the past	
	transverse	Right for the future more often than for the past		Right for the future more often than for the past	
		Having Cues	No Cues	Having Cues	No Cues
Bilinguals in Mandarin	sagittal	Front for the future more often than for the past	Front for the future more often than for the past	Front for the future more often than for the past	Front for the future more often than for the past
	vertical	Up for the past more often than for the future	Up for the future more often than for the past	Up for the past more often than for the future	Up for the future more often than for the past
	transverse	n/a	Right for the future more often than for the past	n/a	Right for the future more often than for the past
Mandarin monolinguals	sagittal	Back for the future more often than for the past	n/p	Back for the future more often than for the past	Front for the future more often than for the past
	vertical	Up for the past more often than for the future	n/p	Up for the past more often than for the future	Up for the future more often than for the past
	transverse	n/a	n/p	n/a	Right for the future more often than for the past

As can be seen, in Table 6.1, the differences between the any-direction condition and the restricted condition occur in the Mandarin monolinguals. They did not show any preferences when there were no cues in the former condition. On the contrary, they behaved like the bilinguals in the Mandarin condition when they were forced to point to only two directions within each

dimension.

Table 6.2: A summary of the results from the sagittal dimension from the three experiments. Dark grey: more forward for the future than for the past, light grey: more forward for the past than for the future, n/p: no preferences, n/a: not applicable, x: results that are inconsistent with the prediction.

Group/condition	Pointing-Restricted		Production		Perception		Walking	
English monolinguals					X		X	
Bilinguals in English			X				n/p X	
	cues	no cues	cues	no cues	cues	no cues	cues	no cues
Bilinguals in Mandarin	X			X		X	n/p X	n/a
Mandarin monolinguals			n/a		n/a		n/a	
	More forward for the future than for the past							
	More backward for the future than for the past							
X	Inconsistent with prediction							
n/p	No preference							
n/a	Not applicable							

Table 6.2 shows a summary of the results for the sagittal dimension across different experiments. Note that when the bilinguals in the Mandarin condition were forced to point directions on the sagittal dimension when there were sagittal cues (the dark grey box with an X for the bilinguals in Mandarin), they pointed front less often for the future and pointed back less often for the past compared with their results when there were no cues. The sagittal cues had an effect on them; however, the effect was not strong enough to change their associations between time and directions.

With all the results listed, the questions listed in Chapter 2 can now be answered.

1. How do English and Mandarin speakers and bilinguals of the two languages associate time with direction on each dimension?

The first experiment adopted a methodology that was used by several existing studies that conducted research on the perception of time, such as Boroditsky (2008), Fuhrman and Boroditsky (2010) and Fuhrman et al. (2011). Pointing with one's fingers is a deictic gesture, which also belongs to gesticulation.

Deictic gestures are used for pointing to both physical and conceptual spaces when accompanying speech. Pointing is also a metaphoric gesture when people use it to point to a conceptual space. For each participant, we gave ten trials at the beginning of the experiment which served to prime them to behave in a way that was consistent with the way they usually point. Therefore, pointing directions for temporal words/phrases makes perfect sense for the participants. I extended the pointing paradigm into a long task by making them point to each time type (i.e., future vs. past) multiple times and asking people to point on different axes.

From the results of the first experiment and from some results of the second experiment, the first question asked in Chapter 2 can now be answered. The two specific questions for the first question will be answered.

- (a) Do native English speakers and native Mandarin speakers have different mental timelines on the sagittal and the vertical dimensions? In other words, will English speakers associate front and up with the future and back and down with the past, and will Mandarin speakers associate back and down with the future and front and up with the past?

Overall, the Mandarin monolinguals and the ME bilinguals used the sagittal dimension more often than either the vertical or the transverse dimension. Such a result is consistent with findings from different studies such as corpus studies (Chen, 2007), pointing tasks (Boroditsky, 2008) and gesture studies (e.g., Gu et al., 2013, 2014). The English monolinguals preferred to use the transverse dimension, but not as frequently as using the sagittal one. This is consistent with Casasanto and Jasmin's (2012) findings, in which they found that English speakers used the sagittal dimension more often when producing elicited gestures and the transverse more often to gesture in spontaneous speech.

Within the sagittal dimension, both the any-direction condition and the sagittal-only condition showed that both the English monolinguals and the bilinguals in the English condition associated front with the future more often than with the past, and they associated back with the past more often than with the future. In other words, the bilinguals in the English condition behaved like the English monolinguals on the sagittal dimension. The only

difference between them was that the associations for the bilinguals in the English condition were weaker than those for the English monolinguals. In both conditions, the bilinguals in the Mandarin condition associated front with the future and back with the past when there were no overt sagittal cues in the temporal words. However, they associated back or less front with the future and less back for the past when there were cues. We can see that when there were no overt cues, the bilinguals in the Mandarin condition behaved as they did in the English condition. These front-to-future and back-to-past mappings in Mandarin are consistent with the idea that the Moving Ego model exists in Mandarin, and this result is also consistent with Chui (2011), in which it was found that the Mandarin speakers pointed back for the past when the gesture accompanied ‘yesterday’, which has no directional cues in Mandarin. However, Mandarin sagittal cues, which provide different directions from English, had an effect on them. For the Mandarin monolinguals, when there were no overt sagittal cues, they had no preference in the any-direction condition, and they associated front with the future and back with the past in the sagittal-only condition. However, when there were sagittal cues, the Mandarin monolinguals associated back with the future and front with the past in both conditions. It can be seen that when there were no cues in the sagittal-only condition, the Mandarin monolinguals behaved in a similar way to the bilinguals. However, not only were the Mandarin monolinguals affected by sagittal cues, but the effect was also stronger for them than for the bilinguals. The Mandarin monolinguals showed no preference on the sagittal dimension when there were no cues. They might use the first condition (any-direction) to make sense of the experiment, which might be caused by the demographics. They received less education on average than the other groups. Despite this, the effect of cues was still observed, suggesting that the immediate effect of cues was strong for Mandarin speakers.

Results from the sagittal dimension from both conditions are consistent with theories and findings from existing studies on how English and Mandarin speakers associate time with space, except that the Mandarin monolinguals showed no preferences in the any-direction condition. Existing studies such as those of Lai and Boroditsky (2013) tested the immediate effect of temporal words with sagittal cues and they found that Mandarin speakers were

more likely to provide sagittal responses after being prompted with temporal words with overt sagittal cues; however, they only tested ME bilinguals with stimuli in Mandarin. Chui (2011) also observed co-speech gestures from a Mandarin speaker. When the speaker described temporal information, he pointed back when talking about things which happened *yesterday*. However, when he said *zhi'qian* (literal meaning before/previous), which has the Mandarin-past-front cue *qian*, he pointed forward. The immediate effect of Mandarin sagittal cues from the current pointing task is consistent with the behaviours that have been observed in Chui's (2011) study. The current study recruited a number of speakers and found a similar effect. Both the Mandarin monolinguals and the bilinguals in the Mandarin condition showed future-to-front and past-to-back cross-domain mappings, which is not against the temporal orders in Mandarin. It has been suggested that both the Moving Ego and Moving Time models exist in Mandarin (Yu, 2012). Mandarin speakers' associations between the future and front and between the past and back are likely to be the Moving Ego model in Mandarin. The associations between the future and front and between the past and back by the English monolinguals and the bilinguals in the English condition are also likely to be the Moving Ego model in English. The inconsistent result in the current study might reveal a possible pattern for Mandarin monolinguals. Temporal direction on the sagittal dimension does not appear to be salient to them unless overt cues appear.

To summarize, results on the sagittal dimension from the different groups showed that English associates front with the future and back with the past, and the bilinguals in the English condition also did so, which also reveals the effect of the English language on the bilinguals. Such findings suggest that the Moving Ego model is dominant in English when people associate time with space. The Mandarin speakers are sensitive to Mandarin sagittal cues and they might have different associations between time and space: front-future and front-past, which are likely to represent the two temporal metaphors in Mandarin: the Moving Ego and Moving Time metaphors. In other words, they may have used the Moving Ego model, and their temporal direction on the sagittal dimension was consistent with the English monolinguals and the bilinguals in the English condition. However, when they used

the Moving Time model, they showed an opposite temporal direction.

On the vertical dimension, both the any-direction condition and the vertical-only condition showed that both the English monolinguals and the bilinguals in the English condition associated up with the future and down with the past, which were inconsistent with the hypotheses. However, the latter group's associations were slightly weaker than those from the former group. In other words, the bilinguals in the English condition behaved in a similar way to the English monolinguals. The bilinguals in the Mandarin condition also showed a similar pattern when there were no overt vertical cues, and their associations were weaker than those when they were in the English context. However, they associated up with the past and down with the future when there were cues. For the Mandarin monolinguals, in both the any-direction condition and the vertical-only condition, they associated up with the past and down with the future when there were overt vertical cues. However, they had no preference when there were no cues in the any-direction condition, and they associated up with the future and down with the past when there were no cues in the vertical-only condition. When in the vertical-only condition, they behaved like the bilinguals in the Mandarin condition. We can see that Mandarin vertical cues had a strong effect on the Mandarin speakers, and the cues can change their associations between time and directions.

According to existing studies (e.g., Fuhrman et al., 2011), Mandarin has up-past and future-down cross-domain mappings. Such mappings are strong when stimuli contain overt vertical cues (Gu et al., 2014; Lai & Boroditsky, 2013). The up-future and down-past cross-domain mappings were also found in the other three groups/conditions. Such a relationship between time and vertical space is not supported by and has rarely been found in Mandarin and English linguistic data, and it has never been found in behavioral experiments (Boroditsky, 2001; Hendricks & Boroditsky, 2015). This particular finding in the current experiment might have to do with the possible projection between the sagittal and vertical dimensions. Correlation tests between sagittal responses and vertical responses from all the fillers suggested that the two dimensions might have a close connection. Such a phenomenon can be seen in daily life. For example, when seeing a sign that shows an up-

ward arrow at an airport, people would know that it means to go forward. Preferences on the vertical dimension might be a projection from the sagittal dimension. However, such a possibility cannot be confirmed without further evidence. The other possibility is that they were caused by the experimental stimuli. Fillers with positive and negative valence made the participants associate up with the future and down with the past. Future studies can test this possibility by removing the fillers and only testing temporal phrases. For the Mandarin monolinguals, who showed no preference on the vertical dimension in the any-direction condition, it might be possible that the vertical temporal direction is only salient when vertical cues exist.

To summarize, results from the vertical dimension showed that the English monolinguals associated up with the future and down with the past, and such associations were also found in the bilinguals in the English condition. For the bilinguals in the Mandarin condition and the Mandarin monolinguals, when there were no vertical cues, they also showed the same direction as that in English. These mappings were unpredicted and required further studies. The effect of vertical cues from Mandarin speakers agrees with the up-past and down-future mappings in Mandarin, which are opposite to those in English. However, the up-future and down-past mappings from all the participants might be caused by a projection between the sagittal and vertical dimensions.

On the transverse dimension, most of the participants associated left with the past and right with the future. Such a fact can be explained by the left-to-right writing and reading directions in both English and in mainland China. Only the Mandarin monolinguals showed no preference in the any-direction condition. We can see that the Mandarin monolinguals consistently showed no preference in the any-direction condition when no cues were involved. As has been discussed, they might use the first condition to make sense of the task, which is based on their demographics. Despite this, they were strongly affected by the cues on the other two dimensions, suggesting that Mandarin speakers are sensitive to spatial cues.

To summarize, almost all the participants showed a left-past/right-future cross-domain mapping, given the fact that both English and Mandarin (used in mainland China) adopt a left-to-right writing direction. Temporal direc-

tions on the transverse dimension are affected by writing and reading directions. We can see that in the current study, English and Mandarin reveal the same temporal direction on the transverse dimension. On the contrary, since Mandarin cues had strong effects on the Mandarin speakers on both the sagittal and vertical dimensions, the English speakers associated front and up with the future and back and down with the past, and Mandarin speakers associated back and down with the future and front and up with the past when there were directional cues. English and Mandarin showed the same temporal directions on the two dimensions when there were not any directional cues in Mandarin.

- (b) If there are differences, will bilinguals associate front with the future and back with the past when speaking English or perceiving temporal information in English?

The answer to this question lies in the findings from the pointing experiment and the body sway experiment. In the pointing experiment, on both the sagittal and vertical dimensions, it was found that the bilinguals' behaviours showed intermediate patterns. On the one hand, the bilinguals in the English condition showed similar patterns to the English monolinguals, and the bilinguals in the Mandarin condition showed similar patterns to the Mandarin monolinguals. On the other hand, bilinguals' associations between time and directions in the English context were slightly weaker than those from the English monolinguals, and the effect of Mandarin cues on the bilinguals in the Mandarin context was weaker than that on the Mandarin monolinguals.

It is suggested that the bilinguals' behaviours in the English context might be affected by their knowledge of Mandarin, and their behaviours in the Mandarin context might be affected by their knowledge of English. However, without knowing the bilinguals' proficiency in each language, the current study cannot draw a direct causality between the effect of language on the perception of time. Nevertheless, we can still see that the bilinguals in the English condition associated front with the future and back with the past.

In the body sway experiment, the two perception tasks revealed that the ME bilinguals in the English context showed front-future and back-past cross-

domain mappings, which were consistent with the Moving Ego model; and in the Mandarin context they showed front-past and back-future mappings, which were consistent with the Moving Time model. Such a difference might reveal the effect of language on bilinguals' space-time cross-domain mappings. However, the effect of language on perception needs to be studied in the future in a more carefully designed experiment where materials about the past and the future are designed as minimal pairs. On the contrary, the effect of the English context was not found in the bilinguals' space-time cross-domain mapping during production, which might be because co-speech body movements are learned early and are less malleable than those produced during listening. Therefore, they are more affected by one's native language.

To summarize, we can see that the English context might have effects on the bilinguals' perception of temporal information during the perception tasks and they associated front with the future and back with the past when listening to the English stories. They also showed the same pattern when pointing directions for English temporal words.

2. If English and Mandarin have different temporal directions on the sagittal dimension, do monolinguals and bilinguals of the two languages have different body sway patterns during the processing of temporal information about the past and the future?

Body sway produced during perceiving and producing temporal information can be seen as a measurement of implicit associations. The current body sway experiment was based on that which was conducted by Miles, Nind, and Macrae (2010) and was extended to different tasks. It tested the potential different body movement patterns between English and Mandarin since it appears that the two languages have different space-time cross-domain mappings on the sagittal dimension.

The second question asks about English and Mandarin speakers' body movement patterns in different language contexts, and it is divided into three sub-questions. The answers to the questions lie within the findings from the body-sway experiment.

- (a) Do native English speakers sway their bodies according to the temporal direction in English during the perception and the production of

temporal information in English?

English has two types of temporal metaphors, and each temporal metaphor has its own temporal direction. In the Moving Ego metaphor the future is ahead and the past is behind, whereas in the Moving Time metaphor the future is behind and the past is ahead. Existing studies have found that when testing English speakers in behavioural experiments, participants associate front with the future and back with the past. Body sway patterns from the English monolinguals during listening are inconsistent with the activation of the Moving Ego metaphor. They swayed more forward for the story about the past than the one about the future. These unpredicted behaviours were not supported by the Moving Ego metaphor and other studies. It remains unclear why the English monolinguals produced these body movement patterns. A possible reason is that it might be caused by the experimental stimuli. Since the stories were not made as minimal pairs, which means there are possible other factors affecting the participants.

Nevertheless, the English monolinguals' body movement patterns are consistent with the Moving Ego metaphor in English in the production task. For the thinking phase, the results are consistent with the existing finding (Miles, Nind, & Macrae, 2010), which means that the task essentially replicates them. The only difference is that the current thinking phase is a preparation phase for producing speech, whereas in their study the thinking phase is not followed by anything. Moreover, the English monolinguals' body movement patterns during talking are also consistent with those from the thinking phase, suggesting that producing temporal information is also accompanied by body sway that is consistent with languages.

To summarize, the English monolinguals' swaying directions in the production task are consistent with the Moving Ego metaphor in English. On the contrary, in the perception experiment and the walking experiment, their behaviours were consistent with future-back and past-front cross-domain mappings, which were not supported by the Moving Ego metaphor. Since both the body sway and walking experiments used the same stories, some unknown factors might affect the English monolinguals in both experiments. For example, participants might prefer one story over the other.

- (b) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in Mandarin during the perception and the production of temporal information in Mandarin?

In fact, for the bilinguals in the Mandarin context, the production task and the two perception tasks showed mostly consistent results. When producing temporal information in Mandarin, the bilinguals swayed more back for the future than for the past during both the thinking and talking phases. In addition, they showed similar moving patterns between questions that had overt sagittal cues and questions that had no such cues.

During the first perception task, when they listened to materials that were in Mandarin, they also swayed more back for the future than for the past. In the second perception task, when looking at the effect of the overall Mandarin context in the second perception task, it was found that the bilinguals swayed more back for the future than for the past regardless of cues when the overall context was Mandarin. The results of the effect of sagittal cues in both the production and the second perception tasks are inconsistent with the pointing experiment, which found that the Mandarin speakers associated front with the future and back with the past when there were no sagittal cues. However, when looking at the effect of the immediate context in the second perception task, it was found that the bilinguals swayed more forward for the future than for the past in both the English and Mandarin contexts. Despite this, the difference between the future and the past was greater when English was the immediate context than when Mandarin was the immediate context, which is also consistent with the pointing experiment. Both perception tasks also showed that the bilinguals swayed more back when they heard the Mandarin-future-back cue and swayed more forward when they heard the Mandarin-past-front cue.

To summarize, bilinguals sway more back for the future than for the past in the Mandarin context, which is consistent with the dominant temporal direction in Mandarin. Results from the bilinguals in the Mandarin conditions revealed a close connection between the processing of temporal information, including producing such information, and body sway. These results suggest that such a connection is not limited to languages that have future-front and

past-back cross-domain mappings, such as English (Miles, Nind, & Macrae, 2010; Sell & Kaschak, 2011) and German (Koch et al., 2011; Ulrich et al., 2012). The connection can also be found in a language that focus on future-back and past-front cross-domain mappings. Despite the consistent results between perception and production, results from the perception still need to be interpreted with caution because of the problem of experimental design.

- (c) Do Mandarin-English bilinguals sway their bodies according to the temporal direction in English or in Mandarin during the perception and the production of temporal information in English?

When answering questions in English, the bilinguals swayed more back for the past than for the future. In other words, their swaying patterns are consistent with the dominant temporal direction in Mandarin. Such a pattern was observed in both the thinking and talking phases.

In both perception tasks, the bilinguals swayed more forward for the future than for the past in the English contexts, which is consistent with the temporal direction of the Moving Ego metaphor in English. We can see that they behaved in a manner consistent with the activation of the Moving Ego metaphor in English when processing auditory linguistic material in English.

The results from the bilinguals in the English conditions might provide evidence for a cross-linguistic effect of language on the processing of temporal information. The bilinguals' body movement pattern was changed when processing auditory linguistic materials in English, which is completely different from the way they behaved in the Mandarin context. Their different body movement patterns between the two different language contexts can be seen as possible evidence for the effect of language on the mental representation of an abstract concept. Despite so, these findings in the perception need to be further tested in the future in a more carefully designed experiment.

To summarize, when in the English context, bilinguals swayed their bodies according to future-front and past-back cross-domain mappings when listening to the stories. However, they moved their bodies according to future-back and past-front cross-domain mappings when thinking about English questions and producing information in English.

3. How general is the effect of temporal perception on body movements?

The effect of perception of temporal information on body movements has been found in the bilinguals but not in the English monolinguals in the two perception tasks. It has also been found that temporal information has an embodied impact. However, a further question is: How general can the effect of temporal information and spatial cues on bodily status be? In order to answer the question, we tested both English monolinguals and bilinguals on how fast they walked when listening to stories about the past and the future. In order to answer the third question, the effect of temporal information on walking speed for each group of participants is asked.

- (a) Do English speakers walk faster when listening to information about the future than when listening to information about the past?

The answer is no. The English monolinguals who listened to the story about the future walked more slowly than ones who listened to the one about the past most of the time. This result is consistent with the English monolinguals' body movement patterns during the first perception task in the body sway experiment, but it is not coherent with the Moving Ego metaphor in English.

- (b) Do Mandarin-English bilinguals walk faster when listening to information about the future than when listening to information about the past in English?

The answer is no. The bilinguals' walking speeds when listening to English materials did not show differences when listening to the story about the future compared to listening to the one about the past.

- (c) Do ME bilinguals walk faster when listening to information about the past than when listening to information about the future in Mandarin?

The answer is also no. Different temporal information in Mandarin did not have an impact on the bilinguals' walking speeds.

We can see that temporal information was not found to significantly affect bilinguals' walking speeds. In other words, the bilinguals walked equally fast when listening to the two Mandarin stories, and they walked equally fast when listening to the two English stories. However, the bilinguals walked significantly faster when listening to the English stories than when listening to the Mandarin stories. These results are consistent with the numbers of stressed words in each story. It was found that the English stories had more stressed words than the Mandarin stories, whereas within each language the story about the future and the one about the past did not differ in terms of the numbers of stressed words. As we can see, stress patterns appeared to play an important role during walking. Despite the fact that there is no evidence suggesting that auditory text could affect people's walking speeds, studies have found that rhythmic auditory stimuli such as music could affect people's walking speeds (Styns et al., 2007). Rhythmicity could have the potential to function as a tool to facilitate biological rhythmical movements and establish rhythmic kinematic patterns (Jylhä, Serafin, & Erkut, 2012). For example, existing studies have looked at the effect of external auditory rhythmic cues on people with Parkinson's disease (McIntosh, Brown, Rice, & Thaut, 1997) and Traumatic Brain Injury (Hurt, Rice, McIntosh, & Thaut, 1998), and found that they can increase walking speeds for a simple task (Suteerawattananon, Morris, Etnyre, Jankovic, & Protas, 2004) and during a dual-task (Rochester et al., 2005). Since language and music share similar dimensions such as pitch, intensity and rhythm, it is reasonable to believe that the numbers of stressed words may be an important factor affecting bilinguals in the current experiment.

The English monolinguals showed unexpected behaviours in the walking experiment. Their behaviours were inconsistent with activation of the Moving Ego metaphor but were consistent with the body sway experiment. The inconsistent effect of temporal information and stressing patterns between the English monolinguals and the bilinguals might be explained by the fundamental differences between English and Mandarin in terms of sentence stress patterns.

English is a stress-timed language and stressed words in a sentence are content words, whereas Mandarin is syllable-timed language (Clark & Yal-

lop, 1995), and stressed words in a sentence are logically and attitudinally prominent words (Li, 2002). Studies looking at sentence stress patterns from Mandarin speakers have found that Mandarin speakers are perceived to have difficulty in locating stress in an English sentence, and although Mandarin speakers could produce sentence stress like English speakers, the acoustic characteristics of their stress reflect those of sentence stress in Mandarin (Chen et al., 2001). Chen et al. (2001) suggest that Mandarin speakers might process rhythm differently than English speakers, and ME bilinguals' processing of English sentence stress could be affected by sentence stress patterns in Mandarin. Some studies that were conducted on bilinguals of English and Asian languages (e.g., Mandarin, Cantonese and Korean) also found L1 interference in producing sentence stress in English (Chen et al., 2001; Ng & Chen, 2011; Trofimovich & Baker, 2006), whereas other studies found L1 interference from Spanish on English sentence stress production (Gutiérrez-Díez, 2001; Nava, 2008). These studies suggest that people process rhythm differently between native and non-native languages.

The other reason for the unexpected behaviours was probably the experimental design. As has been mentioned, both the perception tasks and the walking experiment used the same stimuli: stories that were not designed as minimal pairs. As a result, the walking experiment perhaps has not tested the difference between the future and the past but the difference between the stories. Certain features about the stories caused the results: some of them can be tested such as stress patterns whereas others remain unknown.

To summarize, how general the effect of temporal information on walking remains unclear and requires future research to study the question in a more carefully designed experiment.

4. Could spatial cues in temporal expressions affect how Mandarin speakers perceive time?

In order to answer the question, spatial cues were tested in the three experiments in both explicit and implicit tasks.

- (a) Do Mandarin speakers associate different directions with temporal information that lacks spatial cues than when the temporal information contains the spatial cue front (or back)?

Based on the results of the pointing experiment, it was found that spatial cues on both the sagittal and vertical dimensions can change the Mandarin speakers' association between time and direction. For example, they thought that the future was up when there were no cues; however, they thought that the future was down when there were the Mandarin-future-down cues. The effects of spatial cues from both the sagittal and vertical dimensions are consistent with the immediate effects of Mandarin spatial cues in an explicit task (Lai & Boroditsky, 2013), vertical temporal gestures (Gu et al., 2014) and sagittal temporal gestures (Chui, 2011).

- (b) If yes, can the presence of spatial cues in temporal expression affect Mandarin speakers' body movement patterns (in both body-sway and walking)?

Overall, the bilinguals in the Mandarin condition showed similar moving patterns between materials with sagittal cues and those without them. They moved more forward for the past than for the future in the Mandarin conditions regardless of sagittal cues. Such a pattern was found for both the production task and the second perception task. Nevertheless, if we look at the effect of Mandarin sagittal cues after people heard them, results show that in both perception tasks, sagittal cues have an immediate effect on people's postures despite the problem of the experimental design. Mandarin speakers swayed more back when they heard the Mandarin-future-back cue, and they swayed more forward when they heard the Mandarin-past-front cue. The immediate effect of sagittal cues is consistent with the overall pattern for bilinguals in the Mandarin condition. Moreover, since body sway is considered to be an implicit task, the immediate effect of sagittal cues on body movements is also consistent with the effect of sagittal cues on sagittal temporal gestures (Chui, 2011). However, the immediate effect of sagittal cues in the walking experiment was not found.

6.2 Differences between Experiments

As we can see, different experiments/tasks collected different results. The different results can be explained by the different mechanisms of the tasks.

The pointing task was an explicit task and the participants were more likely to be affected by the current language of the stimuli. For example, the bilinguals in the English condition behaved like the English monolinguals with a slightly weaker association between up and the future; however, when in the Mandarin condition their association between up and the future was weaker than that in the English context even when there were no Mandarin vertical cues. The two perception tasks shared a similarity with the pointing task. In the perception tasks participants also needed to process linguistic materials, despite the fact that they were auditory rather than textual. As a result, the participants in the perception tasks were also likely to be affected by the language of the task. For example, the bilinguals in the English condition swayed more forward for the future than for the past, which is the predominant temporal direction in English, and when they were in the Mandarin context they swayed more forward for the past than for the future.

The two perception tasks were also different. The participants were tested in the two sessions with only one language in each session in the first perception task. On the contrary, the bilinguals in the second perception task were tested in only one session with materials in the two different languages. It seems that in the second perception task, the bilinguals were influenced by the language of the first story, and the influence persisted across time even in the face of inconsistent information from the other language. The persistence of the impact from the very first story is possible, since the language used by the experimenter was consistent with the language of the first story, and all the documents given to the participants were also in the very same language. More importantly, the experimenter was the last “real” person they interacted with, and therefore, the language used by the experimenter gave them a contextual impression. As a result, the overall context was more strongly established.

The perception tasks were also different from the production task, which can be revealed from results from the bilinguals. Since the perception task involves processing linguistic material, the language of the material might have a strong effect on them and consequently they activated the Moving Ego metaphor, in which the future is associated with front and the past is associated with back.

On the contrary, the production task required participants to think and talk. Although thinking and talking also involve processing of linguistic material, it is likely that the body movement patterns accompanying speech are more affected by native language. This is perhaps the reason for the bilinguals to behave according to Mandarin when in the English context in the production task. This is also the possible reason for the bilinguals to behave in a consistent way in the Mandarin context regardless of Mandarin sagittal cues in the production task and in the second perception task. Since the Moving Time metaphor is dominant in Mandarin (Yu, 1998, 2012), that is, future-back and past-front cross-domain mappings, body movement patterns during producing speech are less malleable. Therefore, Mandarin speakers always sway their bodies in such a way even when sagittal cues do not exist.

The walking experiment was also different from the other two experiments. It was found that the bilinguals walked significantly faster in the English condition than in the Mandarin condition, and they walked at equal speeds between the two stories within each language. It appears that the number of stressed words could be an important factor affecting the bilinguals given the fact that people process sentence stress differently in Mandarin/native language and English/non-native language. In other words, the bilinguals' walking speeds were likely to be affected by the rhythm of the stimuli.

As may be seen, participants in different tasks are affected by different main factors. This also suggests that the results collected from different experiments are affected by the particular designs of the experiments (Walker et al., 2014). Bilinguals are more affected by the languages of the task during perception, whereas they are more affected by their native language during production. Therefore, using different tasks can be seen as a strength. People who are going to study the processing of temporal information, temporal metaphor or other types of conceptual metaphors in the future should pay attention to the selection of methodologies and obviously need to be careful about overgeneralizing results gleaned from a single type of experiment. Conducting multiple experiments can contribute to a better understanding of how a conceptual metaphor works.

6.3 *The Current Findings' Relationship to CMT and Embodied Cognition*

The current study is based on CMT (Lakoff & Johnson, 1980/2003) from an embodied point of view (Gibbs et al., 2004; Lakoff & Johnson, 1999). Based on CMT, an abstract concept such as time is both structural and orientational. It means that time is associated with directions, and at the same time, time is systematically associated with space in a given language. In the current experiment, I tested the connection between time and direction on different axes. In terms of the similarities between space and time, the current study was limited to their directionality. It found that people's perception of time is closely linked to the three dimensions, and within each dimension, time is perceived as if it has directions. The results of the current study are consistent with the theory. Both English and Mandarin use space to encode time, however, as we can see when describing short temporal words related to day, week, month and year, Mandarin heavily relies on spatial words, whereas English does not. Results from the current study are mostly consistent with existing studies on how people associate time with space and directions. For example, it was found that the Mandarin monolinguals used the vertical dimension significantly more often than the English monolinguals; however, Mandarin speakers still used the sagittal dimension more often than using the vertical one. Body sway patterns are mostly consistent with the findings on deictic time and sequential time in English speakers, and sequential time in Mandarin speakers.

The systematic connection between time and space in people's mental representation can be revealed from the current study. The overall results can be explained by the two types of temporal models between English and Mandarin: the Moving Ego model and the Moving Time model. Existing studies have found that English speakers associate the future with front (Miles, Nind, & Macrae, 2010), whereas Mandarin speakers associate the future with back (Fuhrman et al., 2011). We can see that the results that did not involve listening to the (potentially problematic) story stimuli from the English monolinguals in the current study were consistent with those from all these studies. We can see that action/motion is not only needed for

perceiving metaphors (Gibbs, 2013), when people produce temporal information, which is related to space, action is also produced accordingly. This is consistent with the idea that motion is the key to the relationship between the future and the past on the sagittal axis (Boroditsky & Ramscar, 2002; Walker et al., 2014).

For the bilinguals, they might also activate the Moving Ego model in Mandarin, which was revealed by their front-future and back-past associations, and they were affected by Mandarin spatial cues. When thinking and talking about ones' own lives, the bilinguals' results in the Mandarin context were consistent with the activation of the Moving Time model, which was reasonable because that the Moving Time model is the dominant temporal model in Mandarin. However, their results in the English context during thinking and talking were also consistent with the activation of the Moving Time model. It seemed that body sway patterns accompanying speech are affected by native language. Such an explanation can be tested in future studies by comparing ME bilinguals with different levels of Mandarin proficiencies. During the perception tasks, the bilinguals' results in the English condition were consistent with the activation of the Moving Ego model and their results in the Mandarin condition were consistent with the activation of the Moving Time model. In other words, the effects of language on temporal perception in bilinguals was possible and they can be tested in future studies.

Lakoff (1993, p.228) argues that “time should be understood through things and motion”. Not only can motion make people sense time, but the current study also found that the processing of temporal information can cause people to move to the corresponding direction. In terms of how conceptual metaphors are understood, the current study also suggests that in order to understand the mechanism that is behind a conceptual metaphor, studies can rely on testing people's physical responses when processing conceptual metaphors (e.g., Gibbs, 2013). Gibbs (2013) found that perceiving a metaphor requires action or embodied simulation of action described by the metaphor. Findings from the perception tasks and the production task agree with this idea. However, the question is, when spatial words were not used in the stimuli, how could the English monolinguals still behave according to the corresponding direction? In other words, why did the English

monolinguals behave accordingly when the metaphor TIME IS SPACE was not overtly described in the stimuli? A possible reason could be that time is understood through motion/action. Although the current study did not provide direct evidence for modality-specific neural activity, which is considered to be the only method for testing embodied metaphor (e.g., activating the target domain of 'time' should elicit brain activity in certain brain areas that involve bodily motion because 'time is motion', Casasanto & Gijssels, 2015), the current study shows that motion/action might still be needed in order to process temporal information.

Body sway accompanying listening can be seen as action during perceiving the TIME IS SPACE metaphor. In the current study, testing body sway is effective since spatio-temporal metaphors are orientational metaphors, which means that they are based on bodily experience. Collecting non-linguistic responses also avoids the problem of circular argumentation in testing CMT (Murphy, 1996, 1997). The current study provides further evidence for supporting CMT. By observing body movement patterns between languages that have different dominant temporal models, which are the Moving Ego and Moving Time models, the current study shows that testing body sway can be a useful tool and non-linguistic evidence for supporting CMT. Other types of evidence have been collected from behavioural experiments (Boroditsky, 2000), gesture studies (McNeill, 1992) and semantic change through history (cf. Lakoff & Johnson, 1980/2003). Although findings from the current study agree with CMT, the current study only shows that CMT can explain spatio-temporal metaphors: it does not assume that it can provide explanations for other types of metaphor.

As mentioned, the current study found that overtly embedded Mandarin spatial cues could affect how ME bilinguals associate time with directions given the fact that Mandarin heavily relies on spatial words in temporal expressions. This effect suggests that spatial information plays an important role in understanding temporal concepts. Although the current study was not designed to test nor to answer the symmetry between time and space, it agrees with the idea that bodily actions in reachable space may play an important role in grounding the understanding of temporal and spatio-temporal expressions (Walsh, 2003). The current study found that the processing of

temporal information had effects on people's body movements. However, the almost systematic effects of the two types of temporal metaphors were found when movement size was small; in other words, the systematic effects of temporal information on body movements were only found within reachable space. For larger movements such as walking, the systematic effect of temporal information became less clear. It was found that other factors might have stronger or weaker effects than temporal information when producing large movements, such as rhythmic patterns of the stimuli. Due to the problem of the experimental design, this question requires further investigation in the future.

The current study hypothesised that the speakers of two languages that have different temporal directions would produce different body movement patterns and therefore, I conducted the body sway experiment with both English and Mandarin speakers. The results suggest that there is indeed a close connection between producing temporal information and body movements/motion. The opposite temporal directions that exist between English and Mandarin, which is also between the Moving Ego and Moving Time models between the two languages, can be revealed by different body sway patterns between English monolinguals and ME bilinguals. The tasks within the body sway experiment are different in terms of their results and the main factors that could affect the participants. Results reveal that the processing of temporal information such as thinking, and producing this information requires 'action'; whereas perceiving the information might also needs some of 'action'. The findings also agree with the idea, that is, imagination, perceiving and doing are embodied (Gallese & Lakoff, 2005). Nevertheless, the English speakers' results were inconsistent with the hypotheses. This might be caused by the experimental stimuli.

6.4 *Limitations of the Current Study*

Although most of the results from the current study were consistent with the hypothesis and existing studies, there were some unpredicted results and they were also unexplained. The unpredicted results are most likely to be caused by the experimental stimuli, and this is the major limitation of the current

study. For example, in the pointing experiment, most of the fillers have positive and negative valence. This might have led to the future-up and past-down mappings found in most of the participants. Both the perception task and the walking task in the body sway experiment used the same stories that were not carefully designed as minimal pairs, and consequently unpredicted results were mostly found from these two tasks. Although the bilinguals in the perception tasks behaved according to the hypotheses, results from all the participants in the perception tasks and the walking experiment should be interpreted with caution and treated as preliminary results only because the stories were not designed as minimal pairs. There were other unknown factors affecting the participants which need to be controlled in future studies.

6.5 Contribution of the Current Study

Existing studies have tested how English and Mandarin associate time with space. The majority of the studies that tested how people associate time with direction focused on languages that have future-front and past-back mappings, such as English and German, and they often chose to test the Moving Ego metaphor. For Mandarin, although the Moving Time model is theoretically dominant based on linguistic data, little experimental evidence has been collected to support such a view. Some research (Fuhrman et al., 2011; Lai & Boroditsky, 2013) found that activation of future-back and past-front mappings are associated with Mandarin proficiencies in ME bilinguals. Many works have focused on cross-dimensional differences between the two languages but have left the within-dimensional differences untested. The studies that stated that English associates front with the future (e.g., Miles, Nind, & Macrae, 2010; Sell & Kaschak, 2011) and Mandarin associates back with the future (e.g., Alverson, 1994) were oversimplified. The current study raised an issue of using different tasks to reveal how a conceptual metaphor works, and therefore it has the following contributions.

First, the findings from the current study suggest that how people perceive time depends on whether we are talking about the overall metaphor in language, or the particular spatial cues. For example, the Mandarin speakers in the pointing task gave different directions for temporal words that did not

have spatial cues and those had the cues. Such a difference is also consistent with the view that Mandarin has both the Moving Ego and Moving Time metaphors (Yu, 2012). The effects of the cues are consistent with several studies that looked at the immediate effect of spatial words in Mandarin spatio-temporal metaphors, such as Chui (2011), Gu et al. (2014) and Lai and Boroditsky (2013).

Second, many studies using action as responses found results that were consistent with the Moving Ego metaphor. The current study shows that action within reachable space can also be consistent with the Moving Time metaphor in another language. The current study experimentally looked how people physically behaved when processing temporal information when the two languages they speak reveal opposite temporal directions. It found that the bilinguals produced different body movement patterns when processing temporal information in different languages. For body movement patterns in English speakers, the current study replicated the study conducted by Miles, Nind, and Macrae (2010). It is unknown whether the English speakers in their study truly thought about the questions they had been asked. The current study used a production task. The advantage of talking is that the content of people's thoughts can be observed.

Third, in terms of motion, the current study agrees with the idea that motion/action might be needed for understanding and producing conceptual metaphors (Gibbs, 2013). The current study fully explored how body-sway is produced by speakers of two languages that emphasize opposite temporal directions during thinking, talking and listening, which has not been done in the literature. The bilinguals' movement patterns in the Mandarin context in the production task suggest that the future-back and past-front mappings could be the dominant temporal direction in Mandarin if these patterns are indeed learned early. Fuhrman et al. (2011) used a pointing task and found that Mandarin speakers with higher Mandarin proficiencies are more likely to associate the future with back. Whereas the current study found that the future-back and past-front mappings can be revealed from body-sway, which is an implicit task. Taken together, findings from the current study and their study suggest that Mandarin speakers' mental representation of time is consistent with what has been suggested by Yu (2012), who speculated the

temporal direction on the sagittal axis in Mandarin solely based on linguistic data.

Lastly, the current study shows that how people think about time also depends on the particular task at hand. For example, the explicit task and the implicit tasks reveal different results, suggesting that different tasks have different mechanisms. If we look at the mechanisms behind these tasks such as listening, thinking, and speaking, we can see that the bilinguals' unexpected results can be explained and predicted by the different mechanisms. Body movement patterns during listening are more affected by the language context, whereas those during thinking and speaking might be more affected by one's native language. It can be seen that linguistic materials in different languages would lead to the activation of different temporal metaphor, and different tasks have different mechanisms.

As we can see, how people associate time with directions are task-specific. Whether a certain movement pattern will be observed also depends on the nature of the task. Results from existing studies sometimes reveal contradictory results, whereas the current study raises the issue of the importance of conducting different types of tasks. Such an issue can also be one of the major contributions of the current study. For future studies, people need to be more careful, and do more of these types of studies. More importantly, explanations for various tasks in the current study are largely post-hoc. Future follow-up studies need to use the explanations and give specific hypotheses for different tasks, which are also related to some key questions that arise from the current study. These questions are:

1. Will early ME bilinguals' body sway patterns be consistent with the Moving Ego metaphor when producing speech?

ME bilinguals with different levels of language proficiencies could be recruited and tested on whether their behaviours are consistent with the Moving Ego metaphor or the Moving Time metaphor during speech perception and production. English as a native language might have stronger effects on bilinguals with higher English proficiencies, and their body sway patterns accompanying speech are likely to be consistent with the Moving Ego metaphor

during speech production since their body movement patterns accompanying speech are learned early.

2. Will English monolinguals' movement patterns be consistent with the Moving Ego metaphor and will ME bilinguals movement patterns differ according to the language contexts of temporal information they are in?

Future studies should be more careful when designing experimental stimuli. The perception tasks and the walking experiment could be redone if auditory materials as minimal pairs can be carefully designed.

3. Can temporal direction on the vertical direction affect certain body movements vertically?

The current experiment only tests the effect of temporal information on sagittal movements; however, if understanding of time is grounded in physical movements, temporal information should also have an impact on people's vertical movements. Future studies could explore such an impact.

Findings from these types of experiment would be strong evidence for testing the effect of native language on body movement patterns, and for revealing the effect of temporal information on body movements.

6.6 Conclusion

It is almost a shared phenomenon that human languages use space, bodily experience and bodily action to conceive time because time is an abstract concept and it is perceived in a more concrete framework. In fact, our perception of time derives from motion (Lakoff, 1993). Based on CMT from an embodied view, the current study used linguistic stimuli that are temporal expressions to test speakers of Mandarin and English on how their body movement could be affected when processing the expressions. Since it used language as stimuli to test the effect of language on body movements, the current study collected non-linguistic responses.

In Chapter 3, I tested the way bilinguals and monolinguals of English and Mandarin produce deictic gestures when giving them temporal stimuli. The

findings suggest that the two languages have different temporal directions on the sagittal dimension. However, the different directions are mainly caused by the overt spatial cues in Mandarin. In Chapter 4, I analyzed how English monolinguals and Mandarin-English bilinguals move their bodies during thinking, talking and perceiving information about the past and the future as well as the immediate effect of overt Mandarin sagittal cues on body movements. It revealed that the differences in swaying patterns in the production task were mostly consistent with the temporal directions in each language. Although it also found that overt spatial information that is embedded in temporal expression has immediate effects on people's body movement directions, these results and other results from the perception tasks should be interpreted with caution due to some flaws in the experimental design. In Chapter 5, I tested the effect of temporal directions on walking speed and found that the stories' stress patterns might have a strong effect on the bilinguals, whereas results from the English monolinguals were inconsistent with the Moving Ego metaphor. Given that this experiment also used the same stories that were designed for the sway experiment, the results should be treated as preliminary results only. The question of the general effects of temporal information on body movements remain unanswered. It might be that action in reachable space is needed for people to process information about space and time (Sell & Kaschak, 2011; Walsh, 2003).

The findings presented in this thesis reveal that the processing of temporal information about the future and the past can cause people's bodies to move in the corresponding directions. The relationship between swaying forward and swaying backward depends on how time is expressed in a given language. When a bilingual speaker's two languages encode time in different ways, these different metaphorical mappings can be revealed by body movement patterns that are consistent with either his/her first language or second language. More importantly, people are affected by overt spatial information, suggesting that people are capable of responding immediately to what they hear.

In the literature of studying people's perception of time, there is a growing tendency to study the effect of language on perceiving temporal information in bilinguals and the connection between body movements and perceiving

temporal information. However, these studies mostly focus on future-oriented western cultures but rarely on a potential past-oriented culture. Some of these study did not find any results. The current study tests speakers of a language that has the Moving Time metaphor as its dominant temporal model, which is Mandarin, and shows that Mandarin speakers' body movement patterns are consistent with the direction of the Moving Time metaphor that is described by Mandarin linguistic data, which are future-back and past-front. Therefore, it provides more evidence for CMT. Testing body sway patterns is shown to be a useful tool for studying spatio-temporal metaphors. Body movements produced during both listening and thinking can be seen as action, whereas those produced during speech suggest that producing conceptual metaphor also requires action. These results agree with the idea that understanding of abstract concept is based on action (Gibbs, 2013).

I hope both the findings and methodologies in the current study can contribute to the metaphor literature and serve as a stepping stone for anyone who wishes to conduct a similar approach or move a step further in the future. Many gesture studies have been conducted in order to look at cognitive process. However, body sway is rarely tested (there are only two studies to my knowledge, but many have looked at arm movements). Body sway can be seen as a motor response but its uncertainty makes it difficult to define and analyze, especially during perception when there is no vocal response, and not to mention it also carries physiological functions, that is, to achieve stability. Future studies on the relationship between processing temporal information and body movement patterns should also note that the effect of processing temporal information on vertical movements may be tested. Future studies can test the effect of the Moving Time metaphor on body movement patterns and test bilinguals with different levels of language proficiencies in order to look at the effect of one's native language on body movement patterns.

More importantly, cross-domain mappings are different across languages, and the overall set of mappings and phenomenon are much more complicated than oversimplified findings. For future studies, people need to attend more to different types of linguistic material and different types of tasks in order to understand the whole system better.

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Appendix A

Regression Models

A.1 Mixed Effect Logistic Regression Models in the Pointing Experiment

Table A.1: The results of the model testing the effect of time type for the English monolinguals when they gave sagittal responses in the any-direction condition, time type:future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	38.08	19.84	1.919	0.055
time type=past	-79.38	18.55	-4.278	<0.001

Table A.2: The results of the model testing the difference between the bilinguals in the English condition and the English monolinguals when they gave sagittal responses in the any-direction condition, time type: future vs. past, English-m: English monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.821	0.2558	3.209	<0.01
time type=past	-2.4901	0.3961	-6.287	<.001
language=English-m	2.6906	0.7618	3.532	<.001
time type=past:language=English-m	-5.2981	1.2983	-4.081	<.001

Table A.3: The results of the model testing the effect of time type for the bilinguals in the English condition when they gave sagittal responses in the any-direction condition, time type:future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.821	0.2558	3.209	<0.01
time type=past	-2.4902	0.3961	-6.287	<0.001

Table A.4: The results of the model testing the difference between the bilinguals in the Mandarin condition and the Mandarin monolinguals when they gave sagittal responses in the any-direction condition, time type: future vs. past, Mandarin-m: Mandarin monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	-0.3081	0.393	-0.784	0.433
time type=past	-2.2489	0.5508	-4.083	<.001
language=Mandarin-m	-0.5759	0.5492	-1.049	0.294
time type=past:language=Mandarin-m	3.2474	0.6959	4.667	<.001

Table A.5: The results of the model testing the effect of time type for the English monolinguals in the sagittal-only condition, time type:future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.1524	0.8927	4.652	<0.001
time type=past	-7.2008	1.2176	-5.914	<0.001

Table A.6: The results of the model testing the difference between the bilinguals in the English condition and the English monolinguals in the sagittal-only condition, time type: future vs. past, English-m: English monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	1.5825	0.3928	4.029	<.001
time type=past	-3.8435	0.5481	-7.013	<.001
language=English-m	2.2043	0.6474	3.405	<.001
time type=past:language=English-m	-2.6844	0.7751	-3.463	<.001

Table A.7: The results of the model testing the effect of time type for the bilinguals in the English condition in the sagittal-only condition, time type:future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	1.4068	0.2855	4.928	<0.001
time type=past	-3.4531	0.4718	-7.319	<0.001

Table A.8: The results of the model testing the difference between the bilinguals in the English condition and the bilinguals in the Mandarin condition in the sagittal-only condition, time type: future vs. past, English-b: bilinguals in the English condition.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.8573	0.3088	2.776	<0.01
time type=past	-2.4786	0.4047	-6.125	<0.001
language=English-b	0.6403	0.3299	1.941	0.0523
time type=past:language=English-b	-1.1748	0.5128	-2.291	<0.05

Table A.9: The results of the model testing the difference between the bilinguals in the Mandarin condition and the Mandarin monolinguals in the sagittal-only condition, time type: future vs. past, Mandarin-m: Mandarin monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	2.123	1.0861	1.955	0.0506
time type=past	-2.754	1.4167	-1.944	0.0519
language=Mandarin-m	-0.7292	0.9137	-0.798	0.4248
time type=past:language=Mandarin-m	3.105	1.2238	2.537	<0.05

Table A.10: The results of the model testing the effect of time type for the English monolinguals when they gave vertical responses in the any-direction condition, time type:future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	28.84	11.54	2.499	0.01244
time type=past	-39.94	14.9	-2.681	<0.001

Table A.11: The results of the model testing the difference between the bilinguals in the English condition and the English monolinguals when they gave vertical responses in the any-direction condition, time type: future vs. past, English-m: English monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	1.971	1.162	1.697	0.0897
time type=past	-2.587	1.229	-2.104	<0.05
language=English-m	1.082	1.573	0.688	0.4917
time type=past:language=English-m	-3.569	2.03	-1.758	0.0788

Table A.12: The results of the model testing the effect of time type for the bilinguals in the English condition when they gave vertical responses in the any-direction condition, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	1.6774	0.9634	1.741	0.0817
time type=past	-2.1213	0.8641	-2.455	<0.05

Table A.13: The results of the model testing the difference between the bilinguals in the Mandarin condition and the Mandarin monolinguals when they gave vertical responses in the any-direction condition, time type: future vs. past, Mandarin-m: Mandarin monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	2.123	1.0861	1.955	0.0506
time type=past	-2.754	1.4167	-1.944	0.0519
language=Mandarin-m	-0.7292	0.9137	-0.798	0.4248
time type=past:language=Mandarin-m	3.105	1.2238	2.537	<0.05

Table A.14: The results of the model testing the effect of time type for the English monolinguals in the vertical-only condition, time type:future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	4.63	1.284	3.605	<0.001
time type=past	-8.799	2.005	-4.389	<0.001

Table A.15: The results of the model testing the difference between the bilinguals in the English condition and the English monolinguals in the vertical-only condition, time type: future vs. past, English-m: English monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	1.7091	0.4902	3.487	<0.001
time type=past	-4.1463	0.692	-5.992	<0.001
language=English-m	2.2119	0.6583	3.36	<0.001
time type=past:language=English-m	-3.5822	0.8402	-4.264	<0.001

Table A.16: The results of the model testing the effect of time type for the bilinguals in the English condition in the vertical-only condition, time type:future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	1.7371	0.5212	3.333	<0.001
time type=past	-4.2351	0.748	-5.662	<0.001

Table A.17: The results of the model testing the difference between the bilinguals in the English condition and the bilinguals in the Mandarin condition in the vertical-only condition, time type: future vs. past, English-b: bilinguals in the English condition.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.4571	0.3566	1.282	<0.001
time type=past	-0.6539	0.3731	-1.753	<0.001
language=English-b	1.0616	0.3271	3.246	<0.001
time type=past:language=English-b	-3.0463	0.5069	-6.009	<0.001

Table A.18: The results of the model testing the effect of time type for the English monolinguals in the transverse-only condition, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	2.1768	0.3181	6.842	<0.001
time type=past	-4.4592	0.4598	-9.698	<0.001

Table A.19: The results of the model testing the difference between the bilinguals in the English condition and the English monolinguals in the transverse-only condition, time type: future vs. past, English-m: English monolinguals.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.4911	0.1983	2.477	<0.05
time type=past	-1.3121	0.288	-4.556	<0.001
language=English-m	1.6857	0.3749	4.497	<0.001
time type=past:language=English-m	-3.1471	0.5426	-5.8	<0.001

Table A.20: The results of the model testing the effect of time type for the bilinguals in the English condition in the transverse-only condition, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.4911	0.1983	2.477	<0.001
time type=past	-1.3121	0.288	-4.556	<0.001

Table A.21: The results of the model testing the effect of time type for the bilinguals in the Mandarin condition in the transverse-only condition, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.1486	0.1945	0.764	0.44487
time type=past	-0.8425	0.2816	-2.992	<0.01

Table A.22: The results of the model testing the effect of time type for the Mandarin monolinguals in the transverse-only condition, time type: future vs. past.

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	0.6111	0.3521	1.736	0.0826
time type=past	-0.951	0.3092	-3.075	<0.01

A.2 Mixed Effect Linear Models in the Body-sway Experiment

Table A.23: The results of the model testing the immediate effect of Mandarin-future-back (hou) in the Mandarin story about the future in the first perception task.

	Estimate	Std. Error	t value
(Intercept)	-0.0007528	0.004081	-0.184
cue=yes	0.0008675	0.0001026	8.454

Table A.24: The results of the model testing the immediate effect of Mandarin-past-front (qian) in the Mandarin story about the past in the first perception task.

	Estimate	Std. Error	t value
(Intercept)	0.00442	0.002781	1.589
cue=yes	-0.0004143	0.00008766	-4.726

Table A.25: The results of the model testing the immediate effect of future markers in the English story on the English monolinguals in the first perception task.

	Estimate	Std. Error	t value
(Intercept)	0.007124	0.0042	1.696
markers = yes	0.0003211	0.00008518	3.769

Table A.26: The results of the model testing the immediate effect of future markers in the English story on the bilinguals in the English condition in the first perception task.

	Estimate	Std. Error	t value
(Intercept)	0.0002664	0.002779	0.096
markers = yes	-0.0008922	0.00008576	-10.404

Table A.27: The results of the model testing the immediate effect of Mandarin-future-back (hou) in the Mandarin story about the future in the second perception task.

	Estimate	Std. Error	t value
(Intercept)	0.026121	0.054377	0.48
cues=yes	0.035947	0.002789	12.89

Table A.28: The results of the model testing the immediate effect of Mandarin-past-front (qian) in the Mandarin story about the past in the second perception task.

	Estimate	Std. Error	t value
(Intercept)	-0.111366	0.076736	-1.451
cues=yes	-0.008033	0.002458	-3.268

A.3 Mixed Effect Linear Models in the Walking Experiment

Table A.29: The results of the model testing the effect of language condition when bilinguals listened to the stories about the future in the walking experiment, English-b: the bilinguals in the English condition.

	Estimate	Std. Error	t value
(Intercept)	0.9595	0.05854	16.39
language=English-b	0.05923	0.01269	4.666

Table A.30: The results of the model testing the effect of language condition when bilinguals listened to the stories about the past in the walking experiment, English-b: the bilinguals in the English condition.

	Estimate	Std. Error	t value
(Intercept)	0.90876	0.05772	15.745
language=English-b	0.04761	0.01632	2.918

Appendix B

Experimental Materials

B.1 Word List for the Pointing Experiment

Table B.1: Words used in the pointing experiment. Words with * are used for Mandarin monolinguals.

word	type	word	type
anger	Emotion	the year before last	Time
disgust	Emotion	three days ago	Time
humiliation	Emotion	yesterday	Time
negative	Emotion	your ancestors	Time
sadness	Emotion	Auckland/ Shenyang city*	Random non paired
calm	Emotion	Australia/ North Korea*	Random non paired
happiness	Emotion	Central Christchurch/ central city*	Random non paired
loving	Emotion	Dunedin/ Ji Lin city*	Random non paired
pleasure	Emotion	east	Random non paired
positive	Emotion	north	Random non paired
dirty	Health	south	Random non paired
injured	Health	the airport	Random non paired
painful	Health	the beach	Random non paired
sick	Health	the mountains	Random non paired
tired	Health	the Pacific Ocean/Russia*	Random non paired
clean	Health	the river/ the lake*	Random non paired
comfortable	Health	the sky	Random non paired

energetic	Health	Wellington/ Beijing*	Random non paired
healing	Health	west	Random non paired
healthy	Health	your house	Random non paired
future	Time	emotional	Random paired
in four years time	Time	inferior	Random paired
in three days time	Time	losing	Random paired
next month	Time	poverty	Random paired
next Saturday	Time	busy	Random paired
next week	Time	gaining	Random paired
next year	Time	rational	Random paired
the day after tomorrow	Time	relaxed	Random paired
the year 2020	Time	superior	Random paired
the year after next	Time	wealth	Random paired
tomorrow	Time	breakfast	Time of day
your descendants	Time	daytime	Time of day
four years ago	Time	morning	Time of day
last month	Time	noon	Time of day
last Saturday	Time	sunrise	Time of day
last week	Time	afternoon	Time of day
last year	Time	dinner	Time of day
past	Time	midnight	Time of day
the day before yesterday	Time	night time	Time of day
the year 1990	Time	sunset	Time of day

B.2 Stories

Mandarin past story without cues

杰克是一名企业的职员，今年28岁。23岁大学毕业那年
Jake BE one CL company of employee this-year 28 age. 23 age university graduate that-year
Jake is an employee at a company and 28 years old this year. He graduated when 23,

他一开始找工作，几经辗转他去过了很多地方，
PN.3.SG.M begin look-for job server pass move PN.3.SG.M go pass PRF.PTC many of place
and started to look for a job. He has been to many places,

也换过几个工作，25岁那年他在当地找到了一份
also change pass some CL job 25 age that-year PN.3.SG.M at local find PRF.PTC one CL
and been worked at different places. When he was 25, he found a job in this city.

工作，他感觉这份工作有挑战性，同事们对他很
job, PN.3.SG.M feel this CL job have challenging colleague PL all treat PN.3.SG.M very
He felt that this job was a challenge to him. Colleagues were friendly,

友好，他也结交到了一些新朋友。努力的工作加上一些
friendly PN.3.SG.M also make-friend PRF.PTC some new friend hard of work plus some
and he made some new friends. As he worked hard and had achieved some

业绩，26岁那年他在单位的职位就获得了提升。
goal 26 age that-year PN.3.SG.M at workplace of position then gain PRF.PTC promotion
goals, he was promoted when he was 26.

尽管杰克在过去的两年里生活比较顺利，但是小时候的他
although Jake at past of two-year in life relatively smooth, but little time of PN.3.SG.M
Although things went well for him in the past two years, when he was a kid his life was

生活很不稳定。因为父亲工作的原因，5岁那年他的父母
life very NEG stable because father job of reason, 5 age that-year POS.3.SG.M parent
not stable. Because of his father's job, when he was 5, his parents

带着他离开了老家。在他的记忆中
bring PROG.PTC PN.3.SG.M leave PRF.PTC hometown at POS.3.SG.M memory in
and he left his hometown. In his memory

他的童年没有在一个地方呆过超过两年，
POS.3.SG.M childhood NEG at same one CL place stay pass exceed two year
he never spent more than two months at one place during his childhood.

当年年仅10岁的他去过的地方就已经比同龄
that-year age only 10 age of PN.3.SG.M go pass of place then already compare same-age
By the age of 10 he had been to more places than most children at that age,

孩子 多了 很多. 也 正 是因为 他的 这样的经历,
Child many.COMP many also right BE because POS.3.SG.M this of experience
and his experience

成为 了 他 在工作 中的宝贵的 财富 圣诞节 还没有 到,
become PRF.PTC PN.3.SG.M at work in of valuable asset. Christmas still NEG arrive
became his valuable asset in his work. Christmas has not arrived yet,

杰克的 工作 依旧 很 忙. 早 在 2月 的时候, 他 就 和 一 个
Jake POS work still very busy. Early at February of time, PN.3.SG.M then and one CL
Jake's work is so busy. Earlier in February, he and a

同事 一起 出差 去 外地, 那 一次 的 任务 需要 他们
colleague together business-trip go out-place that once of assignment need PN.3.PL.M
colleague were sent to another city for a business trip. The assignment required

在 另一个 城市 呆 两 个月. 在那 两 个月 中, 他 白天 在
at another city stay two CL month at that two CL month in, PN.3.SG.M daytime at
two months work at that city. During his life in that city, during daytime he

合作的 公司 里干活, 晚上有时 在 阳台 里 看 书.
cooperative company in work, night sometimes at balcony in look book
he worked on his assignment, and after work he did some reading on his balcony

4 月份 的 时候 他 就 完成 了 任务 并 回到 了 总部
April of time PN.3.SG.M then finish PRF.PTC assignment and return PRF.PTC head-quarter
He came back with his colleague in April.

就 在 他 觉得 上 半 年 即将 过去 的 时候, 6 月初 他 接
just at PN.3.SG.M feel up half year about go of time, June early PN.3.SG.M receive
Just when he felt the first half of the year was about to finish, in early June he received

到了 一 个 大学 同学 哈利 的 电话, 说是 马上 要 到 这个 城市
PRF.PTC one CL university classmate Harry of telephone say BE soon about arrive this city
a phone call from Harry, who was his classmate in his college, saying that he would come to

来, 希望 他 可以 先 帮忙 找 一 下 住房. 哈利 7 月初 来 到了
come, hope PN.3.SG.M may first help find apartment Harry July early come PRF.PTC
the city soon, and asking Jake help him find an apartment. In early July Harry arrived in

这个 城市, 杰克 去 飞机场 接 了 他 并带 他 到了 找 到
this city Jake go airport pick PRF.PTC PN.3.SG.M bring PN.3.SG.M PRF.PTC find PRF.PTC
the city. Jake picked him up at the airport and took him to his

的 公寓. 晚上 他们 去 附近 的 酒吧 喝 了 一 杯.
of apartment. Evening PN.3.PL.M go nearby of bar drink PRF.PTC one glass
apartment. later in the evening they went to a bar and celebrated the reunion with a drink.

Mandarin future story without cues

哈利 对 他的 工作 很 满意 并且 享受 着 自己的 每一 天 的 生活。
Harry towards POS.3.SG.M job very satisfied and enjoy PROG.PTC self of everyday of life
Harry has a job that he likes and he enjoys his everyday life.

但是 他 还是 对 未来 有 一些 计划. 他 做 了 一个 计划 列表。
but PN.3.SG.M still towards future have some plan PN.3.SG.M make PRF.PT one plan list
However, he still has some plans for the future. He made a 'to-do' list.

但 他 没有 太 多 时 间 来 完 成 他 的 计 划, 所 以 他 只 好 计 划
but PN.3.SG.M NEG too many time to finish POS.3.SG.M plan, so PN.3.SG.M only plan
He doesn't have much time for them so he can only hope

在 周 末 或 是 放 假 的 时 候 来 进 行 他 的 活 动. 圣 诞 节 就 要 到
at weekend or holiday of time to ongoing POS.3.SG.M activity Christmas just about arrive
to do them during holidays or weekends. Christmas is approaching.

了, 但是 哈利 要 参 加 一 场 讨 论 会, 参 与 者 都 将 是 他 的 朋 友
PRF.PTC but Harry will participate one CL debate. Participants all will BE POS.3.SG.M friend
Harry is going to give a talk in a debate competition.

杰 克 在 图 书 馆 认 识 的 朋 友, 他 的 朋 友 杰 克 也 会 去 现 场 看 一 看.
Jake at library know of friend POS.3.SG.M friend Jake also would go scene look one look
his friend Jake decides to go there and be supportive along with Jake's friends from a library.

哈 利 计 划 圣 诞 节 期 间 要 去 海 边 和 朋 友 好 好 玩 一 下,
Harry plan Christmas period will go beach and friend good play once
Harry is planning to go to the beach during Christmas and have a good time with his friends.

哈 利 还 打 算 在 圣 诞 节 期 间 去 租 一 间 野 外 小 屋, 带 上 好 朋 友 杰 克 和 自 己
Harry also plan at Christmas period go rent one CL wild cabin, bring good friend Jake and self
Harry is also going to rent a cabin in the woods during Christmas, he will bring his friend Jake and

的 女 朋 友. 他 将 要 准 备 一 些 打 猎 和 钓 鱼 的 工 具, 在 山 里 睡 两 夜.
of girlfriend PN.3.SG.M will prepare some hunt and fishing of tool, at mountain sleep two night
his girlfriend, he is going to prepare some hunting and fishing tools and spend two days there

过 完 新 年 他 会 再 一 次 的 出 差, 而 且 他 2 月 份 就 可 以 回 来,
spend over new year he will again once of business trip and PN.3.SG.M February just can return
He is going to have another business trip after New Year, He can come back in February,

那就意味着出差不会耽误他为女朋友准备
that then mean PROG.PTC business trip NEG will delay PN.3.SG.M for girlfriend prepare
so it won't ruin his plans for Valentine's Day.

情人节计划. 过完情人节, 哈利的父母将会来看他,
of Valentine's day plan spend over Valentine's day Harry of parent will come visit PN.3.SG.M
Harry's parents will come to visit him afterwards,

所以哈利要在附近的旅游景点给他们预定好旅馆, 这样父母
so Harry will at nearby of tourist place for PN.3.PL.M book finish hotel this-way parent
so he will need to book a hotel at the nearest tourist place, and then

来了他可以带他们到处看看, 并且他想让
come PRF.PTC PN.3.SG.M can bring PN.3.PL.M everywhere look, and PN.3.SG.M want let
take them to different places, and he wants

父母见一见他的女朋友, 因为他们打算在不久的将来举行婚礼.
Parents meet POS.3.SG.M girlfriend because PN.3.PL.M plan at NEG long of future hold wedding
his parents to meet his girlfriend, since they are planning to have a wedding in the near future.

父母的旅游计划固然重要, 姐姐的生日也同样重要. 姐姐
parent of travel plan although important elder-sister of birthday also too important elder-sister of
Although his parents' visit is important, his sister's birthday is also important. Sister's

的生日在3月份, 哈利需要考虑下送什么礼物, 这将会是一件很头疼的
of birthday at March Harry need consider send what gift this will BE one CL very headache of
birthday is in March. He needs to consider a gift for her, and it is going to give him a headache.

事情. 哈利还有一些长远的计划. 比如他打算下一个新年
thing. Harry also have some long-term plan example PN.3.SG.M plan next New Year
Harry also has some plans for the next few years. He is dreaming of going to a tropical island

出去旅游, 到一个热带小岛享受一下阳光和沙滩. 他打算
out go travel arrive one CL tropical island enjoy once sunshine and beach PN.3.SG.M plan
for next New Year, and enjoying the sunshine and the beach.

辞职和女友搬回自己的老家, 在自己的老家成立自己的公司,
quit and girlfriend move back self of hometown, at self of hometown establish self of company
He is planning to move back to his hometown with his girlfriend, start his own business

并且在那里举行他们的婚礼.
and at there hold POS.3.PL.M wedding
and have their wedding there.

Mandarin past story with cues

杰克是一名企业的职员，五年前大学毕业开始找工作。
Jake BE one CL company of employee five year before university graduate begin find work
Jake is an employee at a local company. He graduated from a university five years ago and started to

几经辗转他去过很多地方，也换过几份工作。
several pass move PN.3.SG.M go pass PRF.PTC many of place also change pass some CL job
look for a job. He has been to many places, He used to work at different places

虽然那些工作都不错，但他心里觉得这不是他想要的。
although those work all not-bad but PN.3.SG.M heart in feel this NEG BE PN.3.SG.M want of
although these were great jobs, he still felt none of them was the thing he wanted.

三年前他在当地找到了一份工作，他感觉这份工作。
three year before PN.3.SG.M at local find PRF.PT one CL job PN.3.SG.M felt this CL job
Three years ago he found a job in this city. He felt that this job

有挑战性，同事们都很友好，他结交到了一些新朋友，
have challenging colleague PL all very friendly PN.3.SG.M make PRF.PTC some new friend
was a challenge to him. Colleagues were friendly and he made some new friends.

业余偶尔也会找朋友出去活动。努力的工作加上一些业绩，
leisure occasionally also would look for friends go-out activity hard work and some achievement
Occasionally he went out for a trip with them. Since he worked hard and had achieved some goals,

前年他在单位的职位获得了提升。这样他有
front year PN.3.SG.M at workplace of position gain PRF.PTC promotion so PN.3.SG.M have
he was promoted the year before last. As a result, he had more opportunities to going to other places

了更多的出差去外地的机会。四个月前
PRF.PTC COMP many of business trip go out place of opportunities four CL month before
for business trips. Four months ago

他和一个同事一起出差去外地。这一次的任务需要
PN.3.SG.M and one colleague together business trip go out place. This once of mission need
he was sent to another city for a business trip. The assignment required

在另一个城市呆两个月。在出差的过程中，他白天在
at another city stay two CL month at business trip of procedure within PN.3.SG.M daytime at
two months work at that city. During his life in that city, during daytime

合作的公司里干活，晚上有时在阳台里看书，有时则会
cooperative company in work night-time sometimes at balcony in look book sometimes then would
he worked on his assignment, and after work he either did some reading in his balcony or

在一家酒吧里打发时间.两个月前他完成了任务
at one CL bar in spend time two CL month before PN.3.SG.M finish PRF.PTC assignment
stayed in a bar for a while. Two months ago he finished his assignment

并和同事一起回到了总部.回到总部时,
and with colleague together return PRF.PTC head-quarter return PRF.PTC head-quarter when
and came back with his colleague. When he came back,

他继续读那本没有读完的书.三个星期前,他在
PN.3.SG.M continue read that CL NEG read finish of book three CL week before, PN.3.SG.M at
he continued reading his book which he had not finished yet Three weeks ago he

家附近找到了一个图书馆,并在两个星期前正式注册成
home nearby find PRF.PTC one CL library and at two CL week before formal register become
found a library which was near to his apartment, and two weeks ago, he registered as

了会员三天前他接到了一个大学同学
PRF.PTC member three day before PN.3.SG.M receive PRF.PTC one CL university classmate
a member. Three days ago he received a phone call from an university classmate

哈利的电话,说是马上要到这个城市来,希望他可以先
Harry of phone-call say BE immediate will arrive this city come hope PN.3.SG.M could first
Harry, saying that he would come to the city and hope that Jake could

帮忙找一下住房,这个同学以前是他大学时最好的.
help look-for once accommodation this classmate used to BE PN.3.SG.M university when best
do him a favour to find an apartment before he arrived. Harry was his best friends in his college

一个朋友杰克答应了他的请求并在两天前找到了
one friend Jake promise PRF.PTC POS.3.SG.M request and at two day fore found PRF.PTC
Jake agreed to his request and two days ago found

一处住所.这个住所正好离他住的地方不远.哈利的飞机
an apartment, this apartment just-good away PN.3.SG.M live of place NEG far. Harry of plane
an apartment, which was not far from the place he lived in. Harry's plane

前天到达,杰克去飞机场接了他,并带他到
front day arrive Jake go airport pick PRF.PTC PN.3.SG.M and bring PN.3.SG.M arrive
arrived the day before yesterday. Jake went to the airport and brought him to

了找到的公寓哈利非常感谢他的帮忙,
PRF.PTC find of apartment. Harry very thank POS.3.SG.M help
his new home. Harry felt grateful for his help,

晚上他们去附近的酒吧喝了一杯.
Night-time PN.3.PL.M go nearby bar drink PRF.PTC one glass
Later in the evening they went to a pub and celebrated the reunion with a drink.

Mandarin future story with cues

哈利 对 他的 工作 很 满意 并且 享受 着 自己的 每一 天 的 生活。
Harry towards POS.3.SG.M job very satisfied and enjoy PROG.PTC self of everyday of life
Harry has a job that he likes and he enjoys his everyday life.

但是 他 还是 对 未来 有 一些 计划. 他 做 了 一个 计划 列表。
but PN.3.SG.M still towards future have some plan PN.3.SG.M make PRF.PT one plan list
However, he still has some plans for the future. He made a 'to-do' list,

上面 写 着 他的 一些 他 想 做 的 事情. 但 他 没有
on write PROG.PTC POS.3.SG.M some PN.3.SG.M want do of thing but PN.3.SG.M NEG
which contains a list of activities he has been planned. He doesn't have

太 多 时 间 来 完 成 他 的 计 划, 所 以 他 只 好 计 划 在 周 末 或 是 放 假
too many time to finish POS.3.SG.M plan, so PN.3.SG.M only plan at weekend or holiday
too much time for them so he can only hope during holidays or weekend

的 时 候 来 进 行 他 的 活 动. 后 天, 也 就 是 周 六, 哈 利 要 参 加
of time to ongoing POS.3.SG.M activity back day also just BE Saturday Harry want attend
to do them. This Saturday, which is the day after tomorrow, Harry is going to participate in a

一 场 讨 论 会. 参 与 者 都 是 他 的 朋 友 杰 克 在 图 书 馆 认 识 的 朋 友
one CL debate-meeting Participants all BE POS.3.SG.M friend Jake at library known friend
debate competition. The participants will be friends of Jake's at the library

他 的 朋 友 杰 克 也 会 去 现 场 看 一 看. 两 天 后 的 周 日 哈 利
POS.3.SG.M friend Jake also would go scene look one look two day back of Sunday Harry
his friend Jake will go there too. This Sunday, which is in two days' time, Harry

要 去 海 边 逛 一 逛, 带 上 自 己 的 狗 在 周 围 散 步, 顺 便 再 去 书 店,
will go beach walk a walk bring up self of dog at nearby walk convenience also go book shop
is going to the beach to take a walk, bring his dog, go to a book store and

买 一 两 本 旅 游 杂 志. 五 天 后 他 会 再 一 次 的 出 差,
buy one two CL travel magazine five day back PN.3.SG.M will again once of business-trip
buy some travel magazines. He is going to have another business trip in five days' time

虽 然 这 不 是 自 己 的 计 划, 但 是 他 可 以 在 另 一 个 城 市 度 过 下 一 个 周 末
although this NEG BE self of plan but PN.3.SG.M could at another city spend next weekend
even it is not a plan in his list, he can spend next weekend in another city.

对 他 来 说 这 也 是 一 种 休 闲 的 生 活. 两 个 星 期 后, 他 会
For PN.3.SG.M come say this also BE one type enjoyable life two CL week back PN.3.SG.M will
, which is also enjoyable to him. In two weeks' time he is

和 杰克一起 出去野游, 他们 准备好 了 打猎和钓鱼 的工具,
and Jake together out go camping PN.3.PL.M prepare good PRF.PTC hunt and fishing of tool
heading out camping with one of his friends. They have prepared tools for hunting and fishing.

他们 会 在树林 里搭帐篷, 并 在 山 里睡 两 宿. 幸运 的话
PN.3.PL.M will at forest in camping and at mountain in sleep two night luck of say
They are going to spend two days in the forest and sleep in a mountain. Luckily

应该 不 会 遇 到 熊. 三 个 星期 后 父 母 会 来 看 他,
should NEG will meet PRF.PTC bear three CL week back parent will come look PN.3.SG.M
they will not attract bears. His parents will come and visit him in three weeks' time.

哈利 已经 在 附近 的 旅游 圣地 预定 好 了 旅馆, 父 母 来 后 他
Harry already at nearby tourist place book good PRF.PTC hotel parent come after PN.3.SG.M
He will book hotel at the nearest tourist place, and after their arrival he

会 带 着 他们 到处 看看. 两 个 月 后 就 是 圣诞节 了,
will bring PROG.PTC PN.3.PL.M everywhere look two CL month back just BE Christmas PRF.PTC
will take them to different places. It is going to be Christmas in two months' time

正 好 父 母 不 用 回 去, 可以 过 完 新年 后 再 走. 四 个 月 后
right good parent NEG need return may spend finish New Year after then go four CL month back
so his parents do not need to leave until after New Year. In four months' time,

就 是 姐 姐 的 生日 了, 他 正 在 考 虑 自 己 做 一 个 礼 物,
just BE elder-sister of birthday PRF.PTC PN.3.SG.M PROG.PTC consider self make one CL gift
it will his sister's birthday. he is considering making something special for his sister,

但是 还 没 有 想 好 送 什 么. 哈 利 还 有 些 长 远 的 计 划, 比 如 他
But still NEG think good send what Harry still have some long-term of plan example PN.3.SG.M
but still have not made the decision yet. Harry also has some plans for the next a few years. He

打算 后 年 的 新 年 出 去 旅 游, 到 一 个 热 带 小 岛, 享 受 一 下
plan back year of New Year out go travel arrive one CL tropical small island enjoy one time
is dreaming of going to a tropical island the year after next, and enjoying

阳光 和 沙 滩. 他 打 算 两 年 后 开 始 建 立 自 己 的 家 庭.
sunshine and beach PN.3.SG.M plan two year back start build self of family
the sunshine and the beach. He is planning to have his own family in two years' time

然 后 五 年 后 辞 职 成 立 自 己 的 公 司.
then five year back quit-job build self of company
Then quit his job in five years' time and start his own company.

English past story

Harry came to the city years ago after deciding to quit his job in a small company near his hometown. Before he came, he contacted a friend in the city, who had been there for years and had done well in a local company. He asked his friend to find an apartment for him before he came and when he arrived; his friend brought him to his new home. He found the city was big, which was unlike his hometown. He needed time to adjust to the new environment. Luckily his friend provided him with great help. With the help of his friend, he entered a training class in a local company and became a formal employee when he finished the training. He joined a reading group at a local library and attended weekly meetings. Once he was encouraged to give a speech in a group talk and he did it. His friend Jacob went there to support him along with his sister. There Harry met Jacob's sister Sophie and soon they fell in love. They had a beautiful wedding one year later. Then they decided to move back to Harry's hometown, where he found a job as a data processing engineer, and Sophie became a teacher in a local primary school. They bought a house in the suburbs. Jacob came to visit them every Christmas and they liked hearing him talk about his adventures. Harry laughed so hard every time that he heard those crazy things Jacob did. And Jacob was happy to see them; especially he liked to buy presents for his little nephew, Jimmy.

English future story

Harry is satisfied with his current life. His job is well-paid. His wife Sophie likes her job. And their son, Jimmy, is going to a high school, despite his frequent rebellious behaviour. Harry wishes his son to go to a university and learn some specialty subject. But Jimmy wants to go on a journey first. He is going to travel to different places and enter a university when he feels like it. He is going to travel to different countries and experience different cultures, and when he thinks he is ready, he is going to choose a university overseas. But before all of those, he is going to finish high school first. Jimmy's problem isn't the only problem for Harry. He hasn't left the city since his marriage. He hopes to have a vacation so he and Sophie can travel. He is going to make travel plans. Since his old friend Jacob likes adventures, Harry also wishes to do something both meaningful and interesting. He is planning to go to Hawaii for next Christmas, and Sophie certainly would like that, too, because it is going to be their fifteen-year anniversary. But before that, he can go somewhere else on this year's annual leave. They are planning to go to Argentina and enjoy some local festivals. Harry is also interested in making handicraft. He has two plans. He is going to collect some really good looking wine bottles, and use them to make some 'ships in bottles'. There is

going to be a competition next summer, so he will attend the occasion and hope his leisure time is long enough for him to build a fancy one.

B.3 Experimental Instruction in the First Perception Task and the Production Task

B.3.1 Auditory Instruction before the First Perception Task

Mandarin

欢迎来到这个实验,请站在指定的地点,并且不要拿掉戴在你头上的眼罩. 这个实验分成两部分,在完成第二部分之后你可以脱掉你的眼罩. 在第一个部分中你会听到两个故事,你需要仔细听这两个故事并且记住它们的内容. 两个故事之间会有10秒钟的暂停时间.在第二个故事结束之后我们会告诉你接下来要做什么.

English

Welcome to our experiment! Please stand at the marked position and do not try to remove your blindfold. This experiment has two parts, and you can remove the blindfold when we tell you to do so after the second part. In the next part you will hear two stories. You need to listen to the stories carefully and remember the content. There will be a 10 seconds pause after the first story, and after the second story you will be instructed what to do.

B.3.2 Auditory Instruction between Stories in the First Perception Task

Mandarin

请站在指定的地点并且不要脱掉你的眼罩.

English

Please stand at the marked position and do not remove your blindfold.

B.3.3 Auditory Instruction before the Questions

Mandarin

在下一个部分中你将会听到一些问题, 这些问题涉及到你过去的生活和你对未来的计划, 对每个问题你需要仔细的考虑一下, 然后简要的回答问题并且给出一些细节.

English

In the next part you will hear several questions about your life in the past and plans for the future. For each question, think about the answer carefully and talk about it briefly with a little detail.

B.4 Experimental Instruction in the Second Perception Task

B.4.1 Auditory Instruction before the Second Perception Task

Mandarin

欢迎来到这个实验。请站在地上指定的地点并且不要脱掉你的眼罩。在这个实验中你会听到一些故事并且需要回答一些问题。这个实验一共有六个故事，我们会在实验结束时告诉你脱掉眼罩。在每个故事开始前都会有一个介绍说明。在每一个故事结束后你需要脱掉你的眼罩，坐下来，并且回答一些关于这个故事的问题。每个故事我们都会给你一张问卷，在每个故事开始之前我们会让你重新带上眼罩。

English

Welcome to our experiment. Please stand at the marked position and do not try to remove your blindfold. In this experiment you will be listening to several stories and answering a few questions. This experiment has six stories in total, and we will tell you to remove the blindfold at the end of the experiment. At the beginning of each story there will be an introduction. After each story, we will ask you to remove the blindfold, sit down and answer a few questions about the story you have just listened to, we will give you a question sheet for each story. We will ask you to put the blindfold back on at the beginning of each story.

B.4.2 Auditory Instruction between stories the Second Perception Task

Mandarin

请脱掉你的眼罩并且坐下。

请站在指定的地方并且戴上你的眼罩。

在下一个部分中，你将会听到一个中文故事，你需要仔细的听这个故事，并且记住故事的内容。下面是一些提示，记住故事里的人物和他们的名字，他们干了什么还有人物之间的关系是怎样的。请努力的尽可能多的记住故事的内容，因为在故事之后我们会问你一些问题，而且你需要根据故事的内容来回答这些问题。问题会以选择题的方式出现。

English

Please remove the blindfold and sit down.

Please stand at the marked position and put on your blindfold.

In the next part you will hear one English story. You need to listen to the story carefully and remember the content. Here is the hint, remember the characters and their names, what they do and the relationships between them. Please try to remember the content as much as possible, because we will ask you several questions after the story and you will answer the questions according to the story. The format of questions will be in multiple choices.

B.5 Experimental Instruction in the Walking Experiment

Mandarin

欢迎来参加这个实验,接下来你会听到两个故事,在第一个故事开始之前,两个故事之间,和第二个故事结束之后你会听到提示音,提示音将会是这样。“...”

当你听到第一个提示音的时候你需要开始向前行走,当你听到第二个提示音的时候表明第一个故事已经结束并且第二个故事会马上开始,当你听到第三个提示音的时候请停止你的脚步并且站在原地。实验将会马上开始,你将会在5秒钟后听到第一个提示音并且开始步行
感谢你的参与,现在请站在原地不要动,等待实验员的指示。

English

Welcome to our experiment. In the next part you will hear two stories. You will also hear three beeps, one is before the first story, one is between the two stories, and one is after the second story. The beep will be like this: “...”

You will start to walk when you hear the first beep; stories will be played 3 seconds after the first beep. When you hear the second beep, it means the first story is finished and the second one will begin in 3 seconds. The third beep indicates the end of the second story, and you must only stop walking when you hear the third beep. The experiment will start soon. Please try to remember the content of the stories as much as possible. You will hear the first beep in five seconds

Thanks for your participation, please stand at your position and do not move, the experimenter will approach you.

B.6 Consent Forms

B.6.1 Consent Form before the pointing task (Mandarin)

同意表格

研究题目: 测试不同语言的隐喻系统

人类伦理道德委员会审批



这项研究已经通过了坎特伯雷大学人类伦理道德委员会的审批

在你指方向的时候, 实验过程会被摄像机记录下来

含有您个人信息的所有数据, 包括录像, 都会被短期的保存在语言学系, 或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。至于其他一些没有包含您个人信息的数据, 会被保存在有密码保护的坎特伯雷大学服务器上,

请指出您是否同意我们对您的录像做以下的用途。请注意。如果您对所有的问题回答不, 您的录像会被保密地保存起来, 并且除了主要研究员, 任何人都不会对其进行检阅。

1. 静态照片在学术期刊和书籍中的发表 同意/不同意
2. 录像片段用在学术会讲演和讨论中 同意/不同意
3. 录像片段用在教学中 同意/不同意
4. 录像片段用在对这项研究的媒体报道中 同意/不同意

我已经阅读并理解了研究信息中描述的实验步骤。对于我对实验的问题我已经得到了满意的回答, 并且我同意参加这个实验。我知道我对于录像用途的意见会被严格的遵守。

参与者名字 _____

签名 _____ 日期 _____

B.6.2 Consent Form before the pointing task (English)

Consent Form

Full Project Title: Testing Metaphoric Coupling

for Different Language Speakers

HUMAN ETHICS COMMITTEE APPROVAL



This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury.

In this study you will be video-recorded, while pointing in various directions.

All data with identifying information (including video files) will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (<http://www.nzilbb.canterbury.ac.nz/> in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information.

Please indicate whether you would be comfortable with the following uses of your video-recording. Note that if you answer No to all questions then your recording will be kept confidential and not viewed by any individuals except the primary researchers in this study.

1. Publication of still-photos in journal articles and books Yes /No
2. Use of excerpts in conference presentations and talks Yes/No
3. Use of excerpts in teaching Yes/No
4. Use of excerpts in media coverage about this study Yes/No

I have read and I understand the procedures described in the Research Information. My questions have been answered to my satisfaction, and I agree to participate in this study. I understand that my directions regarding the use of my video-recording will be strictly respected.

Name of Subject _____

Signature _____ Date _____

B.6.3 Consent Form before the first perception task (Mandarin)

同意表格

研究题目：测试对记忆的提取和对未来的展

望

人类伦理道德委员会审批



这项研究已经通过了坎特伯雷大学人类伦理道德委员会的审批

在这实验中整个过程会被摄像机记录下来，您需要站着，并且带上眼罩

含有您个人信息的所有数据，包括录像，都会被短期的保存在语言学系，或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。至于其他一些没有包含您个人信息的数据，会被保存在有密码保护的坎特伯雷大学服务器上

请指出您是否同意我们对您的录像做以下的用途。请注意。如果您对所有的问题回答不，您的录像会被保密地保存起来，并且除了主要研究员，任何人都不会对其进行检阅

1. 静态照片在学术期刊和书籍中的发表 同意/不同意
2. 录像片段用在学术会讲演和讨论中 同意/不同意
3. 录像片段用在教学中 同意/不同意
4. 录像片段用在对这项研究的媒体报道中 同意/不同意

我已经阅读并理解了研究信息中描述的实验步骤。对于我对实验的问题我已经得到了满意的回答，并且我同意参加这个实验。我知道我对于录像用途的意见会被严格的遵守。

参与者名字 _____

签名 _____ 日期 _____

B.6.4 Consent Form before the first perception task (English)

Consent Form

Full Project Title: Testing memory retrieval



This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury. Your participation in this study is completely voluntary and you can decide or not to participate in the experiment. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. Withdrawal of participation includes withdrawal of any information already provided. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today.

In this study you will be video-recorded and blindfolded while standing, thinking and talking.

All data with identifying information (including video files) will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (<http://www.nzilbb.canterbury.ac.nz/> in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information. The data will be retained for 10 years, and anonymised data will be put into the NZILBB database.

Please indicate whether you would be comfortable with the following uses of your video-recording. Note that if you answer No to all questions then your recording will be kept confidential and not viewed by any individuals except the primary researchers in this study.

1. Publication of still-photos in journal articles and books Yes /No
2. Use of excerpts in conference presentations and talks Yes/No
3. Use of excerpts in teaching Yes/No
4. Use of excerpts in media coverage about this study Yes/No

I have read and I understand the procedures described in the Research Information. My questions have been answered to my satisfaction, and I agree

to participate in this study. I understand that my directions regarding the use of my video-recording will be strictly respected.

Name of Subject _____

Signature _____ Date _____

B.6.5 Consent Form before the second perception task (Mandarin)

同意表格

研究题目：测试对记忆的提取和对未来的展

望

人类伦理道德委员会审批



这项研究已经通过了坎特伯雷大学人类伦理道德委员会的审批。你对这个实验的参与完全是自愿的，并且你可以觉得是否参与。如果你决定了参与这个实验，您在任何时候都可以退出这个试验并且不用担心惩罚和后果。您的退出就意味着我们会退回您的一切个人信息。请注意一旦你完成了这个实验，你的数据会和其他参与者的数据混在一起并且无法分辨，所以如果你希望移除您的数据，你需要在完成实验前就告诉我们

在这实验中整个过程会被摄像机记录下来，您需要站着，并且带上眼罩

含有您个人信息的所有数据，包括录像，都会被短期的保存在语言学系，或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。至于其他一些没有包含您个人信息的数据，会被保存在有密码保护的坎特伯雷大学服务器上

请指出您是否同意我们对您的录像做以下的用途。请注意。如果您对所有的问题回答不，您的录像会被保密地保存起来，并且除了主要研究员，任何人都不会对其进行检阅

1. 静态照片在学术期刊和书籍中的发表 同意/不同意
2. 录像片段用在学术会讲演和讨论中 同意/不同意
3. 录像片段用在教学中 同意/不同意
4. 录像片段用在对这项研究的媒体报道中 同意/不同意

我已经阅读并理解了研究信息中描述的实验步骤。对于我对实验的问题我已经得到了满意的回答，并且我同意参加这个实验。我知道我对于录像用途的意见会被严格的遵守。

参与者名字 _____

签名 _____ 日期 _____

B.6.6 Consent Form before the second perception task (English)

Consent Form

Full Project Title: Testing memory retrieval



This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury. Your participation in this study is completely voluntary and you can decide or not to participate in the experiment. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. Withdrawal of participation includes withdrawal of any information already provided. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today.

In this study you will be video-recorded and blindfolded while standing.

All data with identifying information (including video files) will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (<http://www.nzilbb.canterbury.ac.nz/> in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information. The data will be retained for 10 years, and anonymised data will be put into the NZILBB database.

Please indicate whether you would be comfortable with the following uses of your video-recording. Note that if you answer No to all questions then your recording will be kept confidential and not viewed by any individuals except the primary researchers in this study.

1. Publication of still-photos in journal articles and books Yes /No
2. Use of excerpts in conference presentations and talks Yes/No
3. Use of excerpts in teaching Yes/No
4. Use of excerpts in media coverage about this study Yes/No

I have read and I understand the procedures described in the Research Information. My questions have been answered to my satisfaction, and I agree to participate in this study. I understand that my directions regarding the use of my video-recording will be strictly respected.

Name of Subject _____

Signature _____ Date _____

B.6.7 Consent Form before the walking experiment (Mandarin)

同意表格

研究题目: 测试人们在步行时对收听资料的

精神集中程度

人类伦理道德委员会审批



这项研究已经通过了坎特伯雷大学人类伦理道德委员会的审批。你对这个实验的参与完全是自愿的，并且你可以觉得是否参与。如果你决定了参与这个实验，您在任何时候都可以退出这个试验并且不用担心惩罚和后果。您的退出就意味着我们会退回您的一切个人信息。请注意一旦你完成了这个实验，你的数据会和其他参与者的数据混在一起并且无法分辨，所以如果你希望移除您的数据，你需要在完成实验前就告诉我们

在这实验中您需要带着我们的手机并且进行步行，与此同时您需要用耳机来收听资料。在您完成步行之后，我们要问您一些关于资料的内容的问题。这样是用来检查您是否仔细收听了我们的资料

含有您个人信息的所有数据，包括录像，都会被短期的保存在语言学系，或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。至于其他一些没有包含您个人信息的数据，会被保存在有密码保护的坎特伯雷大学服务器上，数据会保存十年，匿名数据将被保存在研究所的服务器上

我已经阅读并理解了研究信息中描述的实验步骤。对于我对实验的问题我已经得到了满意的回答，并且我同意参加这个实验。我知道我对于录像用途的意见会被严格的遵守。

参与者名字 _____

签名 _____

日期 _____

B.6.8 Consent Form before the walking experiment (English)

Consent Form

Full Project Title: a parallel task of concentration

on listening and physical action



This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury. Your participation in this study is completely voluntary and you can decide or not to participate in the experiment. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. Withdrawal of participation includes withdrawal of any information already provided. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today.

In this study you will be walking while carrying an audio player in a bag, so you will be listening to auditory materials. After finishing walking, you need to answer a few questions about the content of the materials, which is to check whether you have carefully listened to them.

All data with identifying information will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (<http://www.nzilbb.canterbury.ac.nz/> in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information. The data will be retained for 10 years, and anonymised data will be put into the NZILBB database.

I have read and I understand the procedures described in the Research Information. My questions have been answered to my satisfaction, and I agree to participate in this study. I understand that my directions regarding the use of my video-recording will be strictly respected.

Name of Subject _____

Signature _____ Date _____

B.7 Questionnaire

B.7.1 Questionnaire(Mandarin)

背景调查

感谢您参与这个实验



1. 年龄: _____

2. 性别: 男 女

除了普通话, 如果您还可以(将近)流利地说其他语言, 请写出他们, 并且回答下面的问题

语言1: _____

1. 我的普通话比这个语言流利. 是的/不是的
2. 我在7岁之前就会说这种语言了. 是的/不是的
3. 比起这种语言, 我说普通话的时候更多一些. 是的/不是的
4. 我在家主要说这种语言. 是的/不是的
5. 我和朋友之间主要通过这种语言交流. 是的/不是的
6. 我可以流利用这种语言进行舒适的交谈. 是的/不是的

语言2: _____

1. 我的普通话比这个语言流利. 是的/不是的
2. 我在7岁之前就会说这种语言了. 是的/不是的
3. 比起这种语言, 我说普通话的时候更多一些. 是的/不是的
4. 我在家主要说这种语言. 是的/不是的
5. 我和朋友之间主要通过这种语言交流. 是的/不是的
6. 我可以流利用这种语言进行舒适的交谈. 是的/不是的

语言3: _____

1. 我的普通话比这个语言流利. 是的/不是的
2. 我在7岁之前就会说这种语言了. 是的/不是的
3. 比起这种语言, 我说普通话的时候更多一些. 是的/不是的
4. 我在家主要说这种语言. 是的/不是的
5. 我和朋友之间主要通过这种语言交流. 是的/不是的
6. 我可以流利用这种语言进行舒适的交谈. 是的/不是的

B.7.2 Questionnaire(English)

Background Questionnaire

Thank you for taking part in our study



1. Age: _____

2. Sex: M F

If you are a (near-) fluent speaker of a language other than English, please list that language (or languages) below, and answer the following questions

Language 1: _____

1. My English is stronger than this language. Agree / Disagree
2. I have known this language since before I was 7 years old. Agree / Disagree
3. I spend more time speaking English than this language. Agree / Disagree
4. This is the language I mainly speak at Home. Agree / Disagree
5. This is the language I mainly speak with my friends. Agree / Disagree
6. I can hold a fluent comfortable conversation in this language. Agree / Disagree

Language 2: _____

1. My English is stronger than this language. Agree / Disagree
2. I have known this language since before I was 7 years old. Agree / Disagree
3. I spend more time speaking English than this language. Agree / Disagree
4. This is the language I mainly speak at Home. Agree / Disagree
5. This is the language I mainly speak with my friends. Agree / Disagree
6. I can hold a fluent comfortable conversation in this language. Agree / Disagree

Language 3: _____

1. My English is stronger than this language. Agree / Disagree

2. I have known this language since before I was 7 years old. Agree / Disagree
3. I spend more time speaking English than this language. Agree / Disagree
4. This is the language I mainly speak at Home. Agree / Disagree
5. This is the language I mainly speak with my friends. Agree / Disagree
6. I can hold a fluent comfortable conversation in this language. Agree / Disagree

B.8 Information Sheet

B.8.1 Information sheet for the pointing experiment (Mandarin)

研究简介

题目：测试不同语言的隐喻系统



我们邀请您来参加这个实验，作为坎特伯雷大学博士论文的要求，这个实验是在孙可一的指导下进行的。这项研究是在Jennifer Hay 和Lucy Johnston两位教授的监督下进行的。我们的兴趣在于研究个人如何对过去和未来进行思考的。在这个实验中你会看到一些词语，对每一个词语你需要用手指指出你觉得它在哪个方向。

如果你会说多种语言，你可能会被要求用不同的语言来做这个实验，请仔细阅读下面的说明，在参与之前如果有任何不明白的事情，请提出疑问。

参与和撤销

你对这个实验的参与完全是自愿的，并且你可以觉得是否参与。如果你决定了参与这个实验，您在任何时候都可以退出这个试验并且不用担心惩罚和后果。您的退出就意味着我们会退回您的一切个人信息。请注意一旦你完成了这个实验，你的数据会和其他参与者的数据混在一起并且无法分辨，所以如果你希望移除您的数据，你需要在完成实验前就告诉我们。研究员在某种条件下可能会决定撤销您的实验结果。

实验的目的

这个实验的目的是研究语言的隐喻系统

实验过程

您所要做的是用您的手指指出方向，你需要仔细阅读实验中的说明。你讲

先会看到实验说明，它会告诉你对每个词语你只能指一个方向。在每次指出方向之后，你需要用你指方向的手按下键盘上的‘空格’键，这样你就会看到下一个词语。整个过程会用摄像机记录下来，这样是为了日后我们核对结果。

潜在的风险和不适

没有潜在的风险和不适

潜在的好处

这个研究的可能意义在于对说不同语言的人的不同行为作出解释，并且帮助文化之间的交流和理解。对您个人来说没有任何好处。如果您想要一份发表的结果和论文，请联系ksu25@uclive.ac.nz.

对您参与的支付

您会收到小份额的报酬

信息的保密

您在这实验中透露的任何个人信息我们都会给予保密。只有在您允许的情况下才可以透露。这些条款你会在接下来的另一份文件中签署。实验的结果将会被发表，但是您会以匿名的形势出现。没有您的允许我们不会使用任何你的视频。含有您个人信息的所有数据，包括录像，都会被短期的保存在语言学系，或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。至于其他一些没有包含您个人信息的数据，会被保存在有密码保护的坎特伯雷大学服务器上，这些数据都不包含您的个人信息。

对研究的鉴定

如果您对这个实验有任何的问题，请随时通过邮件,ksu25@uclive.ac.nz 来联系孙可一，或是教授Jennifer Hay, jen.hay@canterbury.ac.nz。他们会很高兴的与您讨论关于您的这实验的一些想法。

参与者的权利

对于您对这个实验的参与，您不会放弃任何合法要求，权利，和司法救助。

人类伦理道德委员会批准

这项研究已经通过了坎特伯利大学人类伦理道德委员会的批准

B.8.2 Information sheet for the pointing experiment (English)

Research Information

Full Project Title: Testing Metaphoric Coupling
for Different Language Speakers



You are asked to participate in a research study conducted by Keyi Sun as the main part of the course requirements for a PhD Thesis at the University of Canterbury. A PhD is a public document via the UC library database. This work is conducted under the supervision of Professor Jennifer Hay and Professor Lucy Johnston. We are interested in how individuals associate concepts with direction differently. For example, most people would think of 'heaven' as being up, and 'the centre of the earth' as being down. But people might differ in terms of the directions the associate with things like happiness and sadness, or the future and the past. In this experiment you'll be presented with a series of concepts and asked to point in the direction that you associate with those concepts. If you speak multiple languages, you may be asked to do the task in more than one language. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary and you can decide or not to participate the experiment. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. Withdrawal of participation includes withdrawal of any information already provided. The investigator may withdraw you from this research if circumstances arise which warrant doing to. For example, such circumstances include the possibility that your background is not compatible with the desired demographic for this study, or that the recording equipment may be malfunctioning during the interview.

PURPOSE OF THE STUDY

The purpose of this research is to determine how individuals associate directions with concepts differently, and whether this is affected by the languages they speak.

PROCEDURES

Your involvement in this project will involve pointing directions, and you

need to listen to instructions carefully. You will hear the instructions which will tell you to point one direction at a time. After pointing each direction you need to use the same hand to press a button to hear another instruction. The whole process will be video-recorded. The whole process will take about twenty minutes and it takes place in the NZILBB (<http://www.nzilbb.canterbury.ac.nz/>) observation lab.

POTENTIAL RISKS AND DISCOMFORTS

There are no potential risks or discomforts.

POTENTIAL BENEFITS

This research may have implications for explaining different behaviors performed by different language speakers, and help cross-cultural communication. There will be no benefits to you, personally. If you would like a copy of any published paper reporting the results, please email ksu25@uclive.ac.nz.

PAYMENT FOR PARTICIPATION

You will receive a \$10 voucher.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Any videoing could be entirely confidential if the participant so wishes. The results of this study may be published, but your anonymity will be preserved. You will be identified by number, not by name. All data with identifying information (including video files) will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Keyi Sun at ksu25@uclive.ac.nz or the supervisor Jennifer Hay at jen.hay@canterbury.ac.nz. They would be pleased to discuss any concerns you may have about participation in the project.

RIGHTS OF RESEARCH SUBJECTS

You are not waiving any legal claims, rights or remedies because of your participation in this study.

HUMAN ETHICS COMMITTEE APPROVAL

This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury.

B.8.3 Information sheet for the first perception task (Mandarin)

研究简介

题目：测试对记忆的提取和对未来的展望



我们邀请您来参加这个实验，作为坎特伯雷大学博士论文的要求，这个实验是在孙可一的指导下进行的。这项研究是在Jennifer Hay 和Lucy Johnston两位教授的监督下进行的。我们的兴趣在于研究个人如何对过去和未来进行思考的。在这个实验中你会先听到几个故事。然后我们会问你一些关于你的过去和将来的问题，你需要仔细考虑一下这些问题然后作出回答。如果你会说多种语言，你可能会被要求用不同的语言来做这个实验，请仔细阅读下面的说明，在参与之前如果有任何不明白的事情，请提出疑问。

参与和撤销

你对这个实验的参与完全是自愿的，并且你可以觉得是否参与。如果你决定了参与这个实验，您在任何时候都可以退出这个试验并且不用担心惩罚和后果。您的退出就意味着我们会退回您的一切个人信息。请注意一旦你完成了这个实验，你的数据会和其他参与者的数据混在一起并且无法分辨，所以如果你希望移除您的数据，你需要在完成实验前就告诉我们。

实验的目的

这个实验的目的是研究个人是如何思考和谈论自己的过去和将来的生活的。

实验过程

您所要做的是站立或者舒服的坐着，并且戴上眼罩。你将会先听到两个故事，然后我们会问一些关于你的过去和将来的一些问题。你需要仔细考虑每个问题并且简要的对您的过去和将来的生活进行叙述。整个过程会被摄像机记录。一共会用20-30分钟左右。如果你说两种语言那么你需要来做这个实验两次，实验地点在‘新西兰人机界面技术研究室’中(<http://www.hitlabnz.org/>)。

潜在的风险和不适

没有潜在的风险和不适

潜在的好处

这个研究的可能意义在于对说不同语言的人的不同行为作出解释，并且帮助文化之间的交流和理解。对您个人来说没有任何好处。如果您想要一份发表的结果和论文，请联系ksu25@uclive.ac.nz.

对您参与的支付

您第一次会得到5块钱的购物卷，第二次会得到15块钱的。

信息的保密

您在这实验中透露的任何个人信息我们都会给予保密。只有在您允许的情况下才可以透露。这些条款你会在接下来的另一份文件中签署。实验的结果将会被发表，但是您会以匿名的形势出现。没有您的允许我们不会使用任何你的视频。含有您个人信息的所有数据，包括录像，都会被短期的保存在语言学系，或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。至于其他一些没有包含您个人信息的数据，会被保存在有密码保护的坎特伯雷大学服务器上，这些数据都不包含您的个人信息。

对研究的鉴定

如果您对这个实验有任何的问题，请随时通过邮件,ksu25@uclive.ac.nz 来联系孙可一，或是教授Jennifer Hay, jen.hay@canterbury.ac.nz。他们会很高兴的与您讨论关于您的这实验的一些想法。

参与者的权利

对于您对这个实验的参与，您不会放弃任何合法要求，权利，和司法救助。

人类伦理道德委员会批准

这项研究已经通过了坎特伯利大学人类伦理道德委员会的批准

B.8.4 Information sheet for the first perception task (English)

Research Information

Full Project Title: Testing memory retrieval



You are asked to participate in a research study conducted by Keyi Sun as part of his PhD research at the University of Canterbury. This work is being conducted under the supervision of Professor Jennifer Hay and Professor Lucy Johnston. We are interested in how people think and talk about their

past and future life. In this experiment you will first listen to short stories and then you will be asked a few questions about your past and future. You need to carefully think about each question and talk about it briefly. If you speak multiple languages, you may be asked to do the task in more than one language. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary and you can decide or not to participate in the experiment. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. Withdrawal of participation includes withdrawal of any information already provided. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today.

PURPOSE OF THE STUDY

The purpose of this research is to see how individuals think and talk about their past and future life.

PROCEDURES

Your involvement in this project will involve standing/sitting while wearing a blindfold. You will first listen to two short stories. Then you will be asked questions related to your past and future life. You need to carefully think about it and talk about what your life was like or what your life will be like briefly. The whole process will take 10-20 minutes (for bilingual speakers, you need to come back in order to finish the other 10-20 minutes) and it takes place in the Hitlab NZ

(<http://www.hitlabnz.org/>). The whole process will be video-recorded.

POTENTIAL RISKS AND DISCOMFORTS

There are no potential risks or discomforts.

POTENTIAL BENEFITS

This research may have implications for explaining different behaviors performed by different language speakers, and help cross-cultural communication. There will be no benefits to you, personally. If you would like a copy of any published paper reporting the results, please email ksu25@uclive.ac.nz.

PAYMENT FOR PARTICIPATION

You will receive a \$5 voucher for his/her participation in the first day, and a \$15 voucher will be given for the second part.

CONFIDENTIALITY

Any information that is obtained in connection with this study will remain confidential and will be used only in accordance with your wishes, as indicated on the Consent Form that you will be asked to complete. The results of this study may be published, but your anonymity will be preserved and no video-recordings will be shown without your prior permission. You will be identified by number, not by name. All data with identifying information (including video files) will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information. The data will be retained for 10 years, and anonymised data will be put into the NZILBB database.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Keyi Sun at ksu25@uclive.ac.nz or the supervisor Jennifer Hay at jen.hay@canterbury.ac.nz. They would be pleased to discuss any concerns you may have about participation in the project.

RIGHTS OF RESEARCH SUBJECTS

You are not waiving any legal claims, rights or remedies because of your participation in this study.

HUMAN ETHICS COMMITTEE APPROVAL

This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury.

For contacting Human Ethics Committee
human-ethics@canterbury.ac.nz

University of Canterbury
Te Whare Wānanga o Waitaha
Private Bag 4800
Christchurch 8140, New Zealand

B.8.5 Information sheet for the second perception task (Mandarin)

研究简介

题目：测试对记忆的提取和对未来的展望



我们邀请您来参加这个实验，作为坎特伯雷大学博士论文的要求，这个实验是在孙可一的指导下进行的。这项研究是在Jennifer Hay 和Lucy Johnston两位教授的监督下进行的。我们的兴趣在于研究当人听到不同语言的故事时人的体温的变化。在这个实验中你会先听到几个故事。然后我们会问你一些关于每个故事的内容，在每个故事后我们都会给你一张关于故事内容的问卷。你需要故事的内容然后做出回答。请仔细阅读下面的说明，在参与之前如果有任何不明白的事情，请提出疑问。

参与和撤销

你对这个实验的参与完全是自愿的，并且你可以觉得是否参与。如果你决定了参与这个实验，您在任何时候都可以退出这个试验并且不用担心惩罚和后果。您的退出就意味着我们会退回您的一切个人信息。请注意一旦你完成了这个实验，你的数据会和其他参与者的数据混在一起并且无法分辨，所以如果你希望移除您的数据，你需要在完成实验前就告诉我们。

实验的目的

这个实验的目的是研究个人在听不同语言的故事的时候产生的体温变化。

实验过程

您所要做的是舒服的站立着，并且戴上眼罩。你将会先听到六个故事，然后我们会在每一个故事后都给你一张问卷。整个过程会被摄像机记录。一共会用20-30分钟左右。实验地点在‘新西兰语言大脑和行为研究所’的观察实验室中(<http://www.nzilbb.canterbury.ac.nz/>)。

潜在的风险和不适

没有潜在的风险和不适

潜在的好处

这个研究的可能意义在于对说不同语言的人的不同行为作出解释，并且帮助文化之间的交流和理解。对您个人来说没有任何好处。如果您想要一份发表的结果和论文，请联系ksu25@uclive.ac.nz.

对您参与的支付

您的参与会得到一张\$20的优惠券。

信息的保密

您在这实验中透露的任何个人信息我们都会给予保密。只有在您允许的情况下才可以透露。这些条款你会在接下来的另一份文件中签署。实验的结果将会被发表，但是您会以匿名的形势出现。没有您的允许我们不会使用任何你的视频。含有您个人信息的所有数据，包括录像，都会被短期的保存在语言学系，或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。至于其他一些没有包含您个人信息的数据，会被保存在有密码保护的坎特伯雷大学服务器上，这些数据都不包含您的个人信息。

对研究的鉴定

如果您对这个实验有任何的问题，请随时通过邮件,ksu25@uclive.ac.nz 来联系孙可一，或是教授Jennifer Hay, jen.hay@canterbury.ac.nz。他们会很高兴的与您讨论关于您的这实验的一些想法。

参与者的权利

对于您对这个实验的参与，您不会放弃任何合法要求，权利，和司法救助。

人类伦理道德委员会批准

这项研究已经通过了坎特伯雷大学人类伦理道德委员会的批准

要联系人类伦理道德委员会：

human-ethics@canterbury.ac.nz

坎特伯雷大学

基督城8140，新西兰

B.8.6 Information sheet for the second perception task (English)

Research Information

Full Project Title: Testing memory retrieval



You are asked to participate in a research study conducted by Keyi Sun as part of his PhD research at the University of Canterbury. This work is being conducted under the supervision of Professor Jennifer Hay and Professor Lucy Johnston. We are interested in how body temperatures are different when people listen to stories in different languages. In this experiment you

will first listen to short stories and then you will be asked a few questions about the stories. You need to remember the content and answer a few questions on question sheets. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary and you can decide or not to participate in the experiment. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. Withdrawal of participation includes withdrawal of any information already provided. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today.

PURPOSE OF THE STUDY

The purpose of this research is to see the effect of listening to stories in different languages on people's body temperature.

PROCEDURES

Your involvement in this project will involve standing while wearing a blind-fold. You will first listen to six short stories. You need to answer questions on a question sheet after each story. The whole process will take 20-30 minutes and it takes place in the observation room in the NZILBB (<http://www.nzilbb.canterbury.ac.nz/>) lab. The whole process will be video-recorded.

POTENTIAL RISKS AND DISCOMFORTS

There are no potential risks or discomforts.

POTENTIAL BENEFITS

This research may have implications for explaining different behaviors performed by different language speakers, and help cross-cultural communication. There will be no benefits to you, personally. If you would like a copy of any published paper reporting the results, please email ksu25@uclive.ac.nz.

PAYMENT FOR PARTICIPATION

You will receive a \$20 voucher for your participation.

CONFIDENTIALITY

Any information that is obtained in connection with this study will remain confidential and will be used only in accordance with your wishes, as indicated on the Consent Form that you will be asked to complete. The results of this study may be published, but your anonymity will be preserved and no video-recordings will be shown without your prior permission. You will be identified by number, not by name. All data with identifying information (including video files) will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information. The data will be retained for 10 years, and anonymised data will be put into the NZILBB database.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Keyi Sun at ksu25@uclive.ac.nz or the supervisor Jennifer Hay at jen.hay@canterbury.ac.nz. They would be pleased to discuss any concerns you may have about participation in the project.

RIGHTS OF RESEARCH SUBJECTS

You are not waiving any legal claims, rights or remedies because of your participation in this study.

HUMAN ETHICS COMMITTEE APPROVAL

This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury.

For contacting Human Ethics Committee
human-ethics@canterbury.ac.nz

University of Canterbury
Te Whare Wānanga o Waitaha
Private Bag 4800
Christchurch 8140, New Zealand

B.8.7 Information sheet for the walking experiment(Mandarin)

研究简介

题目: 测试人们在步行时对收听资料的精神集中程度



我们邀请您来参加这个实验，作为坎特伯雷大学博士论文的要求，这个实验是在孙可一的指导下进行的。这项研究是在Jennifer Hay 和Lucy Johnston两位教授的监督下进行的。我们的兴趣在于研究个人如何能同时做两件事情。在这个实验中你将会步行一段距离并且在同时你将会听到一些短故事，之后您需要回答一些问题，是为了检查您是否仔细收听。如果你会说多种语言，你可能会被要求用不同的语言来做这个实验，请仔细阅读下面的说明，在参与之前如果有任何不明白的事情，请提出疑问。

参与和撤销

你对这个实验的参与完全是自愿的，并且你可以觉得是否参与。如果你决定了参与这个实验，您在任何时候都可以退出这个试验并且不用担心惩罚和后果。您的退出就意味着我们会退回您的一切个人信息。请注意一旦你完成了这个实验，你的数据会和其他参与者的数据混在一起并且无法分辨，所以如果你希望移除您的数据，你需要在完成实验前就告诉我们。

实验的目的

这个实验的目的是研究个人是如何能同时做两件事情的。

实验过程

您所要做的是步行一段距离并且同时收听短故事，你需要尽可能的记住故事的内容。步行的距离一共有200米左右，整个过程大概要20分钟（会说两种语言的需要做这个实验两次），实验进行的地点是在ILAM操场的一条大概200米长的距离。步行结束后，我们需要问你一些关于故事的内容的问题，这是为了检查你是否仔细听了故事。

潜在的风险和不适

没有潜在的风险和不适

潜在的好处

这个研究的可能意义在于对说不同语言的人的不同行为作出解释，并且帮助文化之间的交流和理解。对您个人来说没有任何好处。如果您想要一份发表的结果和论文，请联系ksu25@uclive.ac.nz.

对您参与的支付

第一次会得到5块钱的购物卷，第二次会得到15块钱的。

信息的保密

您在这实验中透露的任何个人信息我们都会给予保密。只有在您允许的情况下才可以透露。这些条款你会在接下来的另一份同意条款中签署。实验的结果将会被发表，但是您会以匿名的形势出现。我们会用数字来代替你，而不是名字。含有您个人信息的所有数据，都会被短期的保存在语言学系，或是长期的保存在新西兰语言大脑行为研究所的上锁的房间里。所有的其他数据，会被保存在有密码保护的坎特伯雷大学服务器上，这些数据都不包含您的个人信息。数据会被保存十年，匿名数据会保存在研究所的数据库里。

对研究的鉴定

如果您对这个实验有任何的问题，请随时通过邮件,ksu25@uclive.ac.nz 来联系孙可一，或是教授Jennifer Hay, jen.hay@canterbury.ac.nz。他们会很高兴的与您讨论关于您的这实验的一些想法。

参与者的权利

对于您对这个实验的参与，您不会放弃任何合法要求，权利，和司法救助。

人类伦理道德委员会批准

这项研究已经通过了坎特伯雷大学人类伦理道德委员会的批准

要联系人类伦理道德委员会：

human-ethics@canterbury.ac.nz

坎特伯雷大学

基督城8140，新西兰

B.8.8 Information sheet for the walking experiment (English)

Research Information

Full Project Title: a parallel task of concentration
on listening and physical action



You are asked to participate in a research study conducted by Keyi Sun as part of his PhD research at the University of Canterbury. This work is being conducted under the supervision of Professor Jennifer Hay and Professor Lucy Johnston. We are interested in how well people can do two tasks at

the same time. In this experiment you will be asked to walk for a distance while listening to some auditory materials, and then answer a few questions about the content of the materials. If you speak multiple languages, you may be asked to do the task in more than one language. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

PARTICIPATION AND WITHDRAWAL

Your participation in this study is completely voluntary and you can decide whether or not to participate in the experiment. If you choose to be in this study, you may subsequently withdraw from it at any time without penalty or consequences of any kind. Withdrawal of participation includes withdrawal of any information already provided. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today.

PURPOSE OF THE STUDY

The purpose of this research is to see how individuals behave when being asked to do two tasks at the same time.

PROCEDURES

Your involvement in this project will involve walking for a distance while listening to short stories, for which you need to remember the content as much as you can. The whole distance is approximately 200 meters and the whole process will take about 20 minutes (for bilingual speakers, you need to come back in order to finish the other 200 meters). The experiment takes place on Ilam fields, an approximately 200 meters long walking path. After the walking task, we will ask you several questions regarding the content of the stories, which is to check whether you have carefully listened to the stories.

POTENTIAL RISKS AND DISCOMFORTS

There are no potential risks or discomforts.

POTENTIAL BENEFITS

This research may have implications for explaining different behaviors performed by different language speakers, and help cross-cultural communication. There will be no benefits to you, personally. If you would like a copy of any published paper reporting the results, please email ksu25@uclive.ac.nz.

PAYMENT FOR PARTICIPATION

You will receive a \$10 voucher if you are an English monolingual speaker. A bilingual speaker will receive a \$5 voucher for his/her participation in the first day, and a \$15 voucher will be given for the second part.

CONFIDENTIALITY

Any information that is obtained in connection with this study will remain confidential and will be used only in accordance with your wishes, as indicated on the Consent Form that you will be asked to complete. The results of this study may be published, but your anonymity will be preserved. You will be identified by number, not by name. All data with identifying information will be stored in a locked room in the Department of Linguistics (in the short term) or NZILBB (in the long term) at the University of Canterbury. All other data will be stored on a password protected server at the University of Canterbury. Such data will not contain any identifying information. The data will be retained for 10 years, and anonymised data will be put into the NZILBB database.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Keyi Sun at ksu25@uclive.ac.nz or the supervisor Jennifer Hay at jen.hay@canterbury.ac.nz. They would be pleased to discuss any concerns you may have about participation in the project.

RIGHTS OF RESEARCH SUBJECTS

You are not waiving any legal claims, rights or remedies because of your participation in this study.

HUMAN ETHICS COMMITTEE APPROVAL

This study has been reviewed and approved by the Human Ethics Committee at the University of Canterbury.

For contacting Human Ethics Committee
human-ethics@canterbury.ac.nz

University of Canterbury
Te Whare Wānanga o Waitaha
Private Bag 4800
Christchurch 8140, New Zealand

B.9 Publish Signs

B.9.1 Public Sign for recruiting participants for the pointing experiment

Seeking Speakers of English, Chinese, or Maori

We are conducting a study on pointing. You will be recorded pointing direction with your hand to where you think certain objects or concepts are.



We need three groups of participants for this study:

1. Is New Zealand English the only language you speak?
2. Do you speak English AND Chinese?
3. Do you speak English AND Maori?

If you fall into one of these groups, and are over 18, then please consider helping.

The experiment will take less than an hour, and it is simple and easy. You will receive a \$10 Westfield Voucher for your participation.

If you are interested in helping, please contact ksu25@uclive.ac.nz, or phone 021-2535447. (This research is conducted by a PhD student in linguistics and the project has received University of Canterbury Human Ethics Committee approval)

B.9.2 Public Sign for recruiting participants for the first perception task and the production task

你的母语是中文吗?

Are you a native speaker of Chinese?

We are conducting a study on testing memory retrieval and events planning. You will be recorded when wearing a blindfold and standing comfortably. The only thing you need to do is to listen to short stories and answer a few questions.



We need two groups of participants for this study:

1. Is New Zealand English the only language you speak?
2. Do you speak Chinese and New Zealand English??

If you fall into one of these groups, and are over 18, then please consider helping.

The experiment will take 20 minutes, but you need to come twice if you fall in to group (2), and it is simple and easy.

You will receive a \$10 Westfield Voucher for your participation and people in group (2) will receive a \$5 voucher for the first session, and a \$15 voucher for the completion of the second part.

If you are interested in helping, please contact ksu25@uclive.ac.nz, or phone 021-2535447. (This research is conducted by a PhD student in linguistics and the project has received University of Canterbury Human Ethics Committee approval)

B.9.3 Public Sign for recruiting participants for the second perception task

你的母语是中文吗?

Are you a native speaker of Chinese?

We are conducting a study on testing memory retrieval and events planning. You will be recorded when wearing a blindfold and standing comfortably. The only thing you need to do is to listen to short stories and answer a few questions.



We need one group of participants for this study:

1. Do you speak Mandarin Chinese and New Zealand English?

If you fall into one of these groups, and are over 18, then please consider helping.

The experiment will take about 20-30 minutes, and you only need to come once, and it is simple and easy.

You will receive a \$20 voucher.

If you are interested in helping, please contact ksu25@uclive.ac.nz, or phone 021-2535447. (This research is conducted by a PhD student in linguistics and the project has received University of Canterbury Human Ethics Committee approval)

B.9.4 Public Sign for recruiting participants for the walking experiment

We need English and Chinese speakers

We are conducting a study on a parallel task of concentration of listening and physical action. You will be listening to stories while walking for a distance with a cell phone in your pocket, and then you need to answer a few questions about the content of the stories, which is to test how well you have concentrated on the stories.



We need two groups of participants for this study:

1. Is New Zealand English the only language you speak?
2. Do you speak Chinese and New Zealand English?

If you fall into one of these groups, and are over 18, then please consider helping.

The experiment will take 20 minutes, but you need to come twice if you fall in to group (2), and it is simple and easy.

You will receive a \$10 Westfield Voucher for your participation and people in group (2) will receive a \$5 voucher for the first session, and a \$15 voucher for the completion of the second part.

If you are interested in helping, please contact ksu25@uclive.ac.nz, or phone 021-2535447. (This research is conducted by a PhD student in linguistics and the project has received University of Canterbury Human Ethics Committee approval)

B.10 Debriefing Sheets

B.10.1 Debriefing Sheet after the pointing experiment

Debriefing

Many thanks for your participation in this task. As you know, we were interested in associations between concepts and directions. Some of them were being particularly targeted in this research. We were particularly interested in different associations between time and direction. This is because some languages have metaphors which relate time to direction differently. Our interest is in whether speakers are affected by these metaphors in terms of how they think of time as it relates to direction.

Many thanks for your help.

B.10.2 Debriefing Sheet after the production task

Debriefing

Many thanks for your participation in this task. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today. We need to tell you that the real purpose of this study is not as same as the one you knew before the experiment. The purpose of this study is to see how your body sways when listening to, and thinking and talking about events in the past and in the future. As we know languages associate time with directions in different ways. For example, in English we see the future as in front of us. But in some other languages, the future might be behind people. The stories and questions that you heard are time-related. If you only speak English and when you are listening to the English stories, and thinking and talking about events when the questions are in English, we predict that your body would lean forward when the story and the events are about the future, and backward when they are about the past. However, if you are bilingual, and the other language you speak have a different association between directions and time (such as Chinese), your body sway could be different when the materials are in English and in the other language, according to the temporal metaphors in your language. Therefore, the need for deception is to avoid any effect on body-sway by knowing the purpose before the experiment. Many thanks for your help.

B.10.3 Debriefing Sheet after the second perception task

Debriefing

Many thanks for your participation in this task. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today. We need to tell you that the real purpose of this study is not as same as the one you knew before the experiment. The cell phone we use is not for measuring people's body temperature: it is for tracking body motion. The purpose of this study is to see how your body sways when listening to events in the past and in the future. As we know languages associate time with directions in different ways. For example, in English we see the future as in front of us. But in some other languages, the future might be behind people. The stories that you heard are time-related. When you are listening to the English stories, we predict that your body would lean forward when the story and the events are about

the future, and backward when they are about the past. However, the other language you speak have a different association between directions and time (such as Chinese), your body sway could be different when the materials are in English and in the other language, according to the temporal metaphors in your language. Therefore, the need for deception is to avoid any effect on body-sway by knowing the purpose before the experiment. Many thanks for your help.

B.10.4 Debriefing Sheet after the walking experiment

Debriefing

Many thanks for your participation in this task. Please note that once you have completed the experiment your data will be combined with that from other participants and your data will not be identified. Accordingly if you wish to have your data removed you must indicate this before you complete the experiment and leave the testing session today. We need to tell you that the real purpose of this study is to see how your walking speed changes when listening to stories about the past and the future. The bag you were carrying had a GPS tracking cell phone, which was used as a GPS device to track participants. We test whether past and future-related stimuli would decrease and increase your walking speed. As we know languages associate time with directions in different ways. For example, in English we see the future as in front of us. But in some other languages, the future might be behind people. If you only speak English, it is possible that a future-related story would increase your walking speed and a past-related one would decrease it. However, if you are bilingual, and future is associated with ‘backward’ in the other language you speak, walking speed when listening to a future story in that language would not be as fast as listening to a future story in English. Therefore, the need for deception is to avoid any effect on walking speed by knowing the purpose before the experiment, and we did not want you to walk faster/slower because you knew we were testing your speed. Many thanks for your help.